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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXV.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1892. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1891.

The year commenced with the following disposal of the officers of the Survey:—Mr. Foote in the Cuddapah district of Madras; Mr. Hughes, with Dr. Warth, at the tin exploitation in Tenasserim; Mr. Griesbach proceeding to join the Miranzai Expedition on the North West Frontier; Mr. Oldham, with Sub-Assistants Hira Lal and Kishen Singh, at coal and oil in Baluchistan; Mr. Bose at coal and copper in the Darjiling District and Sikkhim; Dr. Noetling at coal and the demarcation of oil-fields in Upper Burma; Mr. Middlemiss at coal in Hazara, but about to be attached as Geologist with the Black Mountain Expedition; Mr. LaTouche at the exploitation of the Daltongunj coal-field in Bengal; and Mr. Datta at coal in Assam.

Mr. Holland continued at head-quarters in charge of the Museum and Laboratory, in which last, besides the proper research work, considerable endeavour was made to guide the abnormally speculative rush at a development of the gold conditions of Chota Nagpur by numerous assays of reasonably authenticated samples of quartz and other rocks sent to us for determination.

It will thus be seen that the main force of the Department was devoted to economic mineral exploration; though, as the last volume of the published records will show, geological investigation was kept, as much as possible, in parallel working.

PENINSULAR INDIA.

Localization of gold tracts finished.

Madras Presidency.—Mr. Foote's retirement from the service at the end of September last has, for a season at least, closed the survey of the great metalliferous series (Dharwars) of Southern India; still, it is eminently satisfactory that, from an economic research point of view, my esteemed colleague has closed his career after a thorough localization of all the important areas of gold and iron occurrence or production in Madras.

The southerly extension of the Dharwars over the western division of the Cuddapah district was surveyed during the field season, without, however, any further finds having been made of auriferous tracts in that direction.

Just towards the end of the season, and in connection with his visit to the boring for artesian water now being carried out by the Rev. Superior of the Monastery at Place's Gardens, Kilacheri, Chingleput district, Mr. Foote recognized indications in the débris from the bore-hole, which point to no less an important contingency than the existence of a coal-field within 30 miles of Madras. Hitherto, we have only been able to recognize members of the upper division of the Gondwana series in the country south of the Kistna river, though Mr. Foote has all along suspected that a representative of the lower division, or proper coal-bearing series, might underlie the broad alluvial tract of the old Palar river. The boring has now disclosed the fact that the known strata of the locality, which show no trace of carbon, are underlaid by black carbonaceous and bituminous clays, with associated grits and sandstones. So remarkable a difference between the two sets of strata can barely be considered as other than indicating a very decided variation of the circumstances and conditions of formation of the upper group from those prevailing during the deposition of the lower one—which circumstances and conditions, Mr. Foote is led to infer resembled those prevailing in the Lower Gondwana times of the northern part of the peninsula; or, in other words, that there is here hidden away below the Sripermatur beds of Madras a representative of the Indian coal-measures.

Indications of possible coal-fields near Madras.

It is understood that exploration, grounded on Mr. Foote's reading of the evidence brought to light, is about to be instituted under private enterprise, which, as he still remains in India as State Geologist to the Baroda Government, will have the advantage of his watchful advice in its progress. So far, the original boring has reached a depth of 307 feet, and is still in bituminous shale for 25 feet.

Dr. Warth, on transfer from Burma, in August last, was appointed Officiating Superintendent of the Madras Museum; and during his tenure of that office he will keep up a continuance of mineral economic enquiry for the Madras Government until the proper geological survey can be resumed. He has already in this line visited the steatite mines of Betumcherla, in the Kurnool district, in company with me; and the mica mines in the Nellore district with Mr. Holland. The steatite mines which had been decided on by us, and later on by experts in London, as yielding the best stone for the manufacture there of gas-burners, had been reported by the local officials as incapable of yielding blocks of the required sample cube. We found that the thicknesses of the beds are, as a rule, too small to allow of 6-inch cubès; but as there was some cause for assuming that the limit of cube laid down may have been settled at random, considering the small size of the gas-burners, it is possible that the 3 to 4-inch thickness of the "bulpum" beds may not, after trial of the stone sent to England, retard the development of this industry. In any case, a better system of mining than the grubbing work carried on at present will have to be adopted before satisfactory production can be relied on. The opening up of the mica industry at Inakurti, in the Nellore district, is of the greatest importance and interest, as being, I understand, entirely the work of a private explorer and prospector, Mr. Sargent; and because, where I, in my survey of the district some twenty years ago, only saw coarse and irregular crystalline masses of the mineral, the

Kurnool steatite.

Nellore mica development.

largest of which were 4 inches across, the new excavations have yielded great crystals, beautifully clear and without flaws, measuring 2 to 3 feet in diameter and thickness. Additional interest is also attached to this development, as Mr. Holland, in his inspection of the associated rocks, found a splendid specimen of *apatite*, which, if his determination prove correct, is most important, considering the scarcity of that mineral and the rareness of phosphatic sources in India.

Daltongunj coal-field exploration: unfavourable results.

BENGAL PRESIDENCY.—The result of Mr. La Touche's examination of the Daltongunj coal-field by survey and by selection of sites for boring, some of which he carried out himself, is, that I have had to condemn the field in so far as its capabilities were expected to warrant the construction of a railway from Daltongunj to Mogulsarai, the initial object of which was the supplying of coal of a superior quality over the system of railways beyond the latter junction station. Mr. La Touche's report was published in Part 3 of the year's Records; but on it I had already summarized as follows, under date the 26th June:—

"(*a*) The Daltongunj coal-field has an area of about 30 square miles; its strata of sandstone and allied rocks, with seams of coal or carbonaceous shale, are lying in tolerably easy undulations or rolls, although they are at the same time very much cut into and worn away by denudation.

"(*b*) Practically and for all purposes of estimation as to the value of the field, there are only two seams of coal worthy of consideration.

"(*c*) The first or upper seam of coal is very variable in thickness (from 1′ 6″ to 7′ 6″), so much so indeed that any estimate formed as to the total quantity of coal contained within the area of the borings (and these were selected on the best ground) would be unreliable. The coal of this seam is generally very shaly; this appears to be the seam which was worked by Messrs. Hodges and Radford at Singra; it may be called the Singra seam.

"(*d*) The second or lower seam is also very variable, but is generally thicker than the first, running (with variations) from 29 feet to 6 feet in its best development. This is the seam in which the pits belonging to the Bengal Coal Company were formerly worked: it may be called the Pundua seam. It is even difficult here to form a fair estimate of the quantity of coal; but assuming that the thickness of coal in this seam, over an area of one square mile east of Rajhera, is 9 feet, Mr. La Touche reckons that it would furnish a total quantity in round numbers of 9,000,000 tons. Here also the coal is often very shaly.

"(*e*) The more promising boring samples of coal give poor assays: they show, in fact, that the coal is of an inferior kind. (Mr. La Touche does indeed suggest that a fairer estimate of the constitution of the coal should be obtained by trial in bulk, but, as will be seen later on, I question the worth of such a trial.)

"(*f*) The evidence obtained of lower seams than the Pundua seam does not appear to justify any expectation of better coal on a large scale.

"Comparing these results with the previous estimate of Dr. Saise, of a total quantity of not less than 161,377,000 tons of coal containing 11·7 per cent. of ash, and the original estimates of Mr. Theo. Hughes of the Geological Survey, *viz.*, 11,600,000 tons of available coal with, say, 10 to 13 per cent. of ash; and considering that Messrs. Hughes and La Touche are experts in the recognition of strata associated with coal seams in the Indian coal-measures and at following these up or in reasoning as to how they may be expected to continue underground, I have, after careful consideration of the evidences, formed the following conclusion.

"I think this boring exploitation may be taken as conclusive, regarding the inadequacy of the Daltongunj coal-field for meeting the demand required for the proposed railway; although it offers every prospect of meeting local and not very distant demands for fuel.

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"Neither the estimated available tonnage, nor the quality of the coal, have been found to improve on those originally ascertained by Mr Hughes; although I had all along hoped that more detailed examinations and borings might have shown that he was too prone to keep his estimates very well within reasonable probabilities. Mr La Touche's estimate is, of course, only made on a good area of medium thickness coal; but although it could be easily run up to that of Mr. Hughes, I regret that the data before the Geological Survey do not justify our venturing anywhere near Dr. Saise's so much more favourable estimate.

"Mr. La Touche's boring assays are certainly very depressing in their ash percentage· but as I myself have had considerable experience in the Chhattisgarh fields, which, in many respects are like this Daltongunj tract, where the boring samples, notwithstanding my fears of their being mixed with shale, did after all give assays which differed very little from the assays of the coal from trial pits; I therefore do not think that testing in bulk, as suggested by Mr. La Touche, would show any very appreciable improvement in the power of the coal."

The Darjiling coal exploration was continued to the west of the Lisu-Ramthi area surveyed by Mr. Bose during the previous year. The entire Lower Gondwana or Damuda area between Pankhabari and the Tista was examined in some detail, and special attention was paid to the ground just by the Tista Valley cart-road, but the excavations disclosed no promising seams: thus the question of the probable existence of workable seams in this particular area may now be considered as settled.

Darjiling coal survey finished.

The well-known Tindaria outcrops on the Darjiling Railway are in this area and were reported on years ago by Mr. Mallet, though not without considerable doubt as to their ultimate successful development. Mr. Bose does not offer any more encouraging data: indeed he seems to imply that the condition of the coal itself and its mode of occurrence are even more against the working of it than Mr. Mallet was inclined to argue.

Opportunity offering, at the close of this coal exploration, for some further examination of the copper occurrences in Sikkhim, Mr. Bose was posted to this work. He examined sixteen ore localities: only two of these were being worked at the time of his visit, the abandonment of six other places being attributable to the inability of the miners to deal with the influx of water after excavating only to a very moderate depth. Nine ore localities are described as not having been tried at all.

Copper occurrences in Sikkhim; fairly promising.

The mines, or rather burrowings, at Tuk, Bhotang, Ratho and Pachi, appear to be certainly the most promising in all Sikkhim. Mr. Bose thinks that deep mining on modern methods is likely to yield a very fair return at Pachikhani and Rathokhani, where the miners are now at work; and even at the abandoned workings at Tukkhani and Bhotangkhani. It is, of course, questionable whether development in such a distant region, under European enterprise and management, would be a success; but there seems little doubt that a surer prospect of paying return may be anticipated under a more economical and smaller staff of western management and labour than is usually considered necessary in Indian mining ventures, supplemented by reliable trained country labour. I am the more earnest on this point, considering how admirably and successfully such a system was being followed out by Ritter von Schwartz during his management of the Government Iron Works at Barrakar; while I believe that Dr Saise, of the East Indian Railway Co's. coal-fields at Kurhurbari. has also had satisfactory experience of the adaptability of country labour to more responsible work.

Be this as it may, Mr. Bose writes of the four ore localities mentioned above, that Pachikhani appeared to him the most promising, as the existence of at least one rich deposit is known, and that it ought to be tried first in case Sikkhim should attract mining enterprise. A sample, taken at random from the deposit mentioned, yielded 31 per cent of copper; and from what the miners told him, the average yield from the entire mine is about 12 per cent., or 5 seers of copper from one maund of ore. Tukkhani, he thinks, would be a very favourable place for trial after Pachikhani. Mr. Bose's reports on the Continuation of the Darjiling Coal Exploration, and on the Geology and Mineral Resources of Sikkhim were published in the fourth part of the year's volume of the Records.

EXTRA-PENINSULAR INDIA.

Renewed survey of Garo Hills coal: no better results at Goalpara and Rongrengiri.

ASSAM.—Renewed enquiry having been made by the Chief Commissioner of Assam concerning the coal occurrences in the Garo Hills;—and notwithstanding that these places had been visited many years ago, in the first instance, by Mr. Medlicott, and later still by Mr. La Touche, I thought it advisable on several grounds to post Mr. Datta at this work. His attention was first given to the coal indications on the North-West Frontier, in the Goalpara district, close to Singmari on the old Bramaputra. In 1868 Mr. Medlicott reported that "the existence of a fair seam of useful coal at Siju was confirmed, the then value of it being questionable on account of difficulty of access from the plains, across some 10 miles of low, rugged, hills. Of all the known outcrops at Mirampara and Champagiri, a most unfavourable account had to be given: the deposit was indeed the same as at Siju, and more favourably circumstanced for working, the measures being quite horizontal, and close to the surface, but the seam contained only a few irregular little strings of coal in a thick bed of clay, resting almost directly upon a platform of gneissic rocks. The only apparent useful coal there lay in a possible development of the deposit on the same horizon to the deep of the formation in its main basin, on the south of the barrier of crystalline rocks; and I suggested that this point might be determined by a boring in the neighbourhood of Harigaon."

This report of Mr. Medlicott would, on the face of its being the result of so experienced an observer's survey, appear to be a sufficiently exhaustive expression of the poor look-out of the field, except in the direction of Siju; but the now increasing tendency of certain firms of the mercantile community of Calcutta to utilize coal areas adjacent to their planting properties in Assam, seemed to demand such further evidence as could be obtained, especially with regard to this region, and again on the higher country in the neighbourhood of Tura. As was to be expected, Mr. Datta's examination of the first tract only resulted in some further information as to the geological formations and the finding of more outcrops of the same thin coals or carbonaceous shales.

In the Rongrengiri field, he had again to go over ground concerning which Mr. Medlicott had written as follows:—"Some miles up the valley of the Semsang to the west, there is another considerable basin of the coal-measure rocks, occupying the valley above and below the Rongrengiri outpost for a direct distance of seven miles. Locally it is five miles wide. I could nowhere find an outcrop of the coal within this area; but there are stratigraphical features suggesting that it may exist within

the basin at greater depths than the present surface." At a very much later date, Mr. La Touche failed to discover coal seams of any practical value, though he noticed a seam of good coal, one foot thick in a hill, due east of Shemshangiri, and there are several outcrops of a bed of carbonaceous shale, about 3 feet thick, at the west end of the field, which he considered to represent the principal seam of the Darangiri coal-field. Mr. Datta has now furnished a report, in which he adds three outcrops to that mentioned by Mr. La Touche, the thickest being only 18 inches; though on this, he tries to make the very best of a supposition that one seam, averaging 1 foot 3 inches in thickness, may be continuous over 10 square miles. It is with great regret that I am unable to follow him in this estimate: indeed, were the seam tolerably continuous with such a thickness, it is very questionable whether it could be worked, even were the locality less difficult of approach than it is. As a matter of previous survey, the proper and only field in this region offering immediate prospect of successful development is that of Darangiri; for which, too, an application for prospecting and ultimate leasing has been for some time before the Government.

Darangiri, the proper field.

BALUCHISTAN.—The survey for coal and oil having extended over all the country within convenient reach of the railway lines, and in some parts much beyond that, Mr. Oldham's party was withdrawn at the end of the working season. His season commenced by his catching up the Kidderzai field force at Dhanasar, with the object of examining the reported oil occurrence at Kot Moghul, about 13 miles south-east of the Takht-i-Suleiman. Mr. Oldham's condition of health, after an almost continuous field working of eighteen months, prevented his meeting Sir R. Sandeman at Apozai, as had been previously arranged, though he tried his best to do so, and in the end he was only able to establish the bare fact that there is a small outflow of oil. He reported it as of excellent quality, but this estimate was found to be too favourable when the oil was subjected to laboratory judgment. The question of whether the oil existed in sufficient quantity in the strata, or whether it could be more favourably tapped than at the present place of natural issue, could not be determined without a more extensive survey than was then possible; and the carrying out of that will be a troublesome operation, considering that the country is a tribal region on the frontier of the Punjab.

Kot-Moghul oil, on Punjab frontier.

The history of this enquiry, so far, has been given in the second part of the year's volume of the Survey Records, by Mr. Oldham himself, and by Mr. Holland for the laboratory investigation; and it may be as well to summarize it here. In December 1889 a sample, stated to be raw mineral oil, was forwarded to me at the instigation of His Excellency the Commander-in-Chief. This was examined by Mr. Lake in our laboratory and found to have a density of 0·822, and a flashing point of 89° F., which result aroused our suspicions as to the reported source of the oil. Dr. Warden, Chemical Examiner to the Bengal Government, found the specimen submitted to him to have a specific gravity of 0·8209 at 15·5° C., and a flashing point of 89° F.; and he concluded that the specimen was not a crude oil, but a commercial kerosine oil of Russian origin. In September 1890 Dr. Warden reported on a further specimen, procured by the Deputy Commissioner of Dera Ismail Khan, when he found it to have a specific gravity of 0·8154 at 15·5° C. and a flashing point of 84·29° F.

Mr. Oldham was then instructed to visit the locality and send down samples, which, when tried in the laboratory, yielded results showing it to be decidedly inferior in quality, as compared with the other samples.

It has now been decided, in communication with the Dera Ismail Khan authorities, that as soon as arrangements for visiting the country can be settled, a thorough examination of the stratigraphical conditions of the country shall be made with a view to determining the probable underground storage of the oil and the chances of tapping a larger issue by boring.

Mr. Oldham's further work in Baluchistan enabled him to send in reports on an outflow of petroleum in the Robdar Valley, Bolan Pass; on the petroleum resources of the country adjoining the routes to Quetta; and on the coal resources of Quetta and the routes leading to it; while his increased experience of the general stratigraphy of the country conduced to his adding some further evidence in favour of Mr. Medlicott's original suggestion in 1886 for a speculative trial boring near Rohri, on the Indus. As a move in that direction, I have just, at the close of the year, selected places near to and within the North Western Railway works at Sukkur, in view of projected boring operations.

Fuel Conference at Quetta.

In this connection, I attended the Conference on Fuel at Quetta early in December last, when Mr. Oldham's views on the oil conditions of the Khattan field and in the Spintangi Valley were discussed. The test boring recommended by him for the final settlement of the prospects of the Khattan tract is being carried out; but this finality of procedure was very naturally disputed by Sir R. Sandeman, who discovered this oil tract, and by Mr. Townsend, who had superintended all the oil exploitations in Baluchistan until within the last six months. The latter gentleman still relies on certain state breaks or faults in the neighbourhood of Khattan, on the further side of which he considers there is a possibility of oil. Under the circumstances, and feeling that no chance should be allowed to pass of disclosing a larger and freeer issue of oil than has been met with hitherto at this place, I volunteered, notwithstanding the fact that Mr. Oldham's map showed no sign of any marked faulting, to personally examine Mr. Townsend's stated condition of the stratigraphy should the boring now being put down turn out unfavourable to the future of the field. It was also resolved at this Conference, Mr. Townsend and I being in agreement, that a new boring should be put down on the Sind-Pishin Railway, in the Chuppar Rift.

Further report on the Kalka coal: shows unfavourable results.

NORTH-WEST PROVINCES.—The existence of very thin strings of coal and carbonaceous shale at Kalka, in the Simla district, has been known to the Survey for very many years, but the extension of railway communication to that place has naturally aroused renewed speculation as to the value of some lately reported finds; and urgent enquiry was made by the Deputy Commissioner of Simla. Mr. Griesbach examined the country in October, upon which he reports that none of the coal deposits seems to be of any importance. The best exposure is near Kalka, in the valley of the Kassaulia stream, about one and a half miles up-stream from Tipra village and one mile west-south-west from Datiar Chouki on the Simla-Kalka road. The only coal trace in this exposure which might attract notice is an irregular deposit

splitting up into seams, separated by a lenticular bed of sandstone of about 6 inches in thickness. The seam may be estimated as having an average thickness of from 2 to 3 inches, but at one point it is seen to expand to from 8 to 12 inches. The quality of the coal is good enough, and it burns freely, but there is not enough of it to warrant working. Similar traces, all lignite, are found at several localities in the Kalka neighbourhood, and in the Nahan division of the Siwalik formation, but none of them indicate any increase on the estimate formed on the Kassaulia exposure.

Tin exploration in Mergui: very satisfactory progress.

BURMA.—The tin exploitation in Tenasserim, under Mr Hughes, was continued with satisfactory result; a very strong outcrop of the ore-bearing rock itself having been defined within the Maliwun township, from which very encouraging samples of tinstone were obtained. The importance of this find may be gauged when it is considered that this rather abnormal form of lode occurs in the series of rocks constituting the ridges of the country, from the denudation of which the stanniferous alluviums of the valleys have been formed, and that it can hardly be the only good lode of the kind. A considerable part of this lode is so decomposed or weathered as to be sluiceable with profit. The existence of rich alluvial deposits in the Maliwun district is also certain, though they and the rocky zone are not, I fear, rich enough to pay working under, as I have already remarked in connection with copper mining in Sikkhim, elaborate European management and working. The venture must be made under an improved system and encouragement of Chinese working similar to that ruling in the Straits Settlements; and it is satisfactory to note that the labours of Mr. Hughes and his party of prospectors have yielded results which have brought forward applications from syndicates, experienced in that field of operation, for the prospecting and ultimate leasing out of lands in the Maliwun tract. In summarizing the results of the exploitation up to the end of last season's prospecting, Mr. Hughes also considers that he is justified in saying that the alluvial tin in Bahuni, Karathur and Plyngan is of good quality, and such as should yield good returns if worked under fair conditions; meaning, by fair conditions, sufficient means on the part of those who would start work, and readiness on the part of the Local Administration to assist them heartily by carrying out necessary measures.

Much remains to be done in prospecting so large and trackless a region, but I think that by the end of the present season sufficient will have been accomplished, by the Survey of India in topographical surveying, and by ourselves in the demarcation of good tin areas, for the furtherance of a successful tin development by private enterprise.

Upper Burma oil-fields.

In Upper Burma, Dr. Noetling's services have been fully, and, as I understood in personal conference with the Financial Commissioner of Burma, most advantageously employed, not only in the demarcation of the oil-fields, but in the definition of the State wells, and settlement of the rights and position of the Twinzas, or old native miners. At the same time, he has prepared a very elaborate and full memoir on the history and working of the oil-fields, for the Government of Burma.

In view of the extension of a railway to Myingyan, a reconnaissance of the country was made in that direction in the way of prospecting for coal, but without finding outcrops; the result showing that even if the group of coal-bearing rocks

Myingyan coal prospects.

on the eastern side of the Irrawaddi valley does exist on the Myingyan side, it would lie at too prohibitive a depth for working. Towards the close of the year, Dr. Nöetling was despatched to explore the jade and amber tract, being attached to the Column proceeding to Northern Upper Burma. His work in this direction will be good, considering that a portion of his earlier career in Europe was spent at amber mines.

GEOLOGICAL INVESTIGATION.—*Crystalline and Transition Series*.—The season's surveying in the Madras Presidency completed the examination of the larger and more prominent tracts of the Dharwar Series, with their associated older schistose gneisses and granitoids occurring in the very extensive tract of country included in the districts of Anantapur, Bellary, Cuddapah, and Kurnool. This great area, hitherto displayed on our geological map of India as a gneissic region, is therefore now capable of being brought into much nearer formational correlation with Central India and the western frontier of Bengal, where certain groups of transition rocks—notably the 'Gwaliors,' and possibly the 'Bijawars' also—occur as prominent ore-bearing formations. The Madras crystallines, as more recently worked out by Mr. Foote, also appear to have much in common with the Bundelkhund gneiss, as well as that of Bengal. This advance in our knowledge of Madras geology will therefore be of distinct value in the new edition of the Manual of the Geology of India, and its accompanying map, now being written by Mr R. D. Oldham. The more detailed memoir by Mr. Foote is now in press.

South India: North-West Frontier of Punjab: and Sikkhim Himalaya.

In the far distant North-West Frontier, the deputation of Mr Griesbach with the Miranzai Expedittion, and Mr. Middlemiss with the Black Mountain Force, have afforded only slight opportunities of studying the crystallines (igneous and metamorphic) in that direction. Mr. Griesbach's work is embodied in a paper on the geology of the Safed Koh, which will shortly be published.

From the North-East Himalayas, we have useful notes by Mr. Bose on the elevation and disturbance of the Sikkim Himalaya, and on the igneous rocks of Darjiling and Sikkim The former seems to be a pretty direct application of the general results obtained by Mr. Medlicott and Mr. Middlemiss in the Sub Himalaya of the North-Western Provinces.

Cretaceous, Tertiary, and Recent.—From Baluchistan, Mr Oldham has sent in reports on the recent deposits of the valley plains of Quetta, Pishin, and the Dasht-i-Bedaolat; on the geology of the Thal Chotiali and part of the Mari country; on the geology of the country west of the Bolan Pass; and on a tour from Quetta by Kach to Ziarat, Hindubagh.

Baluchistan: and Hazara.

The second of these papers is of special interest as adding a further link to the evidence already gained in peninsular India and Sind, pointing to the occurrence of passage beds which appear to have been deposited during the time interval represented by the gap between the Secondary and Tertiary periods in Europe. Extended survey of the stratigraphical groups already distinguished by Mr. Oldham has shown that his Dunghan group is not only separated from the cretaceous "belemnite beds" below by a slight though distinct unconformable break, unaccompanied by disturbance; but that, while it is an essentially limestone group of great

thickness in the northern part of the area and in the Harnai district, it becomes, to the south-east, an argillaceous one, with only an attenuated limestone facies in its uppermost beds. But with this change, it becomes abundantly fossilliferous, with a fauna having cretaceous and yet decidedly nummulitic affinities. The author is sufficiently guarded in his reading of the unconformability, the change of lithological facies, and the anomalousness of the fauna; but these conditions are fairly open to the interpretation that the Dunghan group probably represents the gap stated above. Mr. Oldham's paper is issued with the current records.

His article on the recent deposits of the valley plains is also published, a feature of interest in it being a discussion of the native "karez" system of tapping water sources at the foot of the flanking hills, and leading it by underground tunnels, or *karezes*, to the lower levels of cultivation. It also treats of the remarkable group of natural artesian springs at Quetta itself; from the study of which and the other conditions of the valley plains the author prepared a note for the Baluchistan Agency on the mode of occurrence and probable distribution of artesian water in the Quetta and Pishin districts.

In Hazara, Mr. Middlemiss's work, early in the season, lay among the lower ranges of hills immediately north of the Rawalpindi plateau, especially along the base of the nummulitic stage, in search of any extension of the Abbottabad coal band, of which however he found no further traces.

A notable feature connected with the recent geology of Hazara is the presence of thick banks of coarse gravel at Diliari and other places, at a height of about 2,000 feet above the level of the Indus. These gravels differ in no way from the beds of gravel at present deposited by that river; and they indicate that combined upheaval of the country and deep cutting of the Indus have resulted in separating the present and past erosion planes of that river by this enormous vertical distance.

Palæontological.—Professor Waagen has been our chief worker. The second part of his *Geological Results*, arising out of his elaborate study of the palæozoic Salt Range fauna, was published early in the year. He continues working at the *Ceratites*, some 20 plates of which are already stored in Calcutta, in readiness for the illustration of the text descriptions.

It hardly becomes me to write in praise of this latest contribution from so distinguished a savant as Dr. Waagen, for it will, indeed has received its meed, in that respect, from the most competent judges in the palæontological world; but the latest testimony I have before me is that his generalizations on the correlation of the Salt Range palæozoics with those of other regions have received remarkable confirmation in the recognition by Oberbergrath Mojsisovics of a Salt Range and Australian faunæ in the collection of carboniferous fossils obtained by the Survey in the North-West Himalaya.

The lamentable death of Professor P. M. Duncan necessitated the transfer of the collections of Kach jurassic *echinoids* and *corals* sent home to him for description, to some other specialist in this section of research;—a contingency for which Dr. Duncan had, as it turned out, thoughtfully provided for by asking Mr. J. W. Gregory, of the Natural History Department of the British Museum, to undertake the work. This arrangement was then confirmed by Dr. Henry Woodward; and we have just received Mr. Gregory's fasciculus on the ECHINOIDEA.

Arrangements have also been made, under the kind guidance of Professor Ed.

Suess of the Imperial University of Vienna, for the study and description of our Himalayan collections by specialists in Austria: Palæozoics, by Dr. Wentzel; Triassics by Oberbergrath Mojsisovics; Rhoêtics, by Dr. Bittner; and Juiassics (Spiti), by Professor Uhlig. In the progress of study so far, Professor Suess reports that our Silurian fossils are rather poor. On the other hand, the very remarkable though not unforeshadowed feature has been recognized, that the carboniferous fossils belong to two very different faunæ, one of the Salt Range type and the other related to Australian carboniferous. The triassic fossils, again, are of such extreme interest as to have induced Professor Suess, in conference with Mojsisovics, to propose the sending out of Privat Docent Dr. Diener, under contributions from the Boué Fund and the Academy of Sciences, for the further collection of fossils, in concert with the Survey, considering, as he does, that "Griesbach's discoveries are so important that it seems well nigh our duty to follow them up as far as we possibly can." Such an implied appreciation of the survey work in Himalayan geology is naturally most gratifying to us; and we too are bound to meet this most liberal and distinguished proposal in as helpful a spirit as can be accorded to us by the Government of India.

Museum and Laboratory.—Mr. Holland is selecting and arranging mineral specimens, models, and drawings to form a collection as an introduction to the study of mineralogy, which will be employed also to illustrate the demonstrations proposed to be given to the students of the Presidency College. Considerable progress has been made towards a more complete arrangement and classification of the rock collection.

The work in the Museum, however, has been considerably delayed on account of the increase in the number of specimens received in the laboratory for determination and analysis. The principal ores assayed during the year were those of gold, silver, lead, tin, copper, and iron; in addition to samples of coal, coke, crude mineral oils, and brines.

Mr. Middlemiss's paper on the Salt Range geology (Records, Vol. XXIII, page 19), published in the beginning of the year, besides adding much of importance to our knowledge of that area, shows that we are not as yet in possession of sufficient data for the satisfactory solution of problems connected with the remarkable position and characteristics of the salt-marl and its associated minerals. As an initial move in the way of solving the questions raised, Mr. Holland has devoted a portion of his leisure to the closer study of rocks collected in this region; and he informs me that the results obtained so far throw considerable light on the local problems besides adding much of general mineralogical interest. Among these may be mentioned the discovery of large proportions of *anhydrite* in the bi-pyramidal quartz crystals ("Mari diamonds"); the occurrence also of anhydrite in the hard nodules of the gypsum beds, and the stages in the process of hydration, with the interesting structures produced during the crystallization of the latter and its intergrowth around fragmentary remains of anhydrite-crystals. The structures produced in these rocks by movements in the mass are also worthy of remark; the gliding planes in the crushed anhydrites and the bent lamellar twinning of the gypsum, passing into stages in which inequiaxed fragments have, by the forced assumption of parallelism, given rise to examples of the most perfect schistosity. Mr Holland concludes that the *data* so obtained offer some

pertinent evidence on one of the long disputed and none the less important questions in the Salt-Range geology—namely, that the gypsum of the localities from which the specimens were obtained is; in its present condition as gypsum, *not* of sedimentary origin. It is interesting to record this result obtained in the laboratory, as it is in precise agreement with the observations made by Mr. Middlemiss in the field.

The Museum Assistant, Mr. T. R. Blyth, has worked well, his carefulness and precision in chemical manipulation being especially commendable.

Survey Publications.—The year's volume of the Records contains 18 Papers, 12 of which deal with industrial or economic subjects: an Index to the first twenty volumes of this series has also been issued. Mr. Griesbach's *Geology of the Central Himalaya* and Mr. Lake's *Geology of South Malabar* also appeared respectively as Volumes XXIII and XXIV, Part III, of the Memoirs of the Geological Survey of India; while the second Part of Volume IV of Professor Waagen's *Salt-Range Fossils* was added to the Palæontologia Indica.

Library.—The additions to the library amounted to 1,501 volumes or parts of volumes, of which 990 were acquired by presentation, and 511 by purchase.

Personnel.—Mr. Lake having been unable, through shattered health, to return to India, on expiry of leave, was permitted to resign the service early in the year. He was thus only able to be with us for the better part of three years, during which time, however, his work was so good and so full of promise for the future that his leaving us was a distinct loss. He contributed one Memoir and three Record Papers to the Survey publications.

The vacancy so caused in our ranks was filled up in October last by the appointment of Mr. W. B. Dallas Edwards, Associate of the Royal College of Science, London.

Our most serious loss, however, has been in the retirement of Mr. Foote, however inevitable this was in the closing years of his extension beyond completed service, which commenced in September 1858.

Mr. Foote was Senior Superintendent of the Survey, and he officiated once as Director for Mr. Medlicott, and again for me, during our absence on leave from India. Nearly all his service was spent in Southern India, the geology, palæontology, prehistoric archæology, and economic resources of which he has investigated with distinguished success. With the exception of the small share I myself had in the original finds, Mr. Foote's name is identified with the discovery of palæolithic remains in India, and especially with descriptions of their occurrence in Southern India, which he further supplemented by a series of valuable observations on the neolithic and later rhistoric occurrences, all of which has conduced to his being accepted as the recognized authority in Europe on this branch of Indian research. At the instance of Professor Huxley, in communication with Sir M. E. Grant Duff, then Governor of Madras, he made an elaborate survey of the Kurnool caves, and exhumed a large collection of mammalian remains of later pleistocene age, among which there is a comparatively large number of species which are either totally extinct, or which are not now found living in India. His discovery also of *Rhinoceros deccanensis*, in the Belgaum district, was an important advance in the study of our pleistocene deposits, while it threw quite a new light on the vexed question of the origin of cotton soil. Our survey of the cretaceous and upper gondwana rocks in Madras rests considerably on his close and observant exploration; and his

distinction of the "Dharwars" among the Transition Series, and following out of the great iron bands in the crystallines of Salem will be of enduring economic value. For the published work of the Survey he has contributed 6 Memoirs, 1 Palæontologia Indica, and 19 Records.

The pleasant satisfaction remaining to us is that Mr. Foote has only severed his connection with the Survey officially: he still remains our colleague in Indian geological work.

WILL. KING,

Director, Geological Survey of India.

January 31st, 1892.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1891.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Museum.
ALLAHABAD.—North-Western Provinces and Oudh Provincial Museum.
BALLARAT.—School of Mines.
BALTIMORE.—Johns Hopkins' University.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN —German Geological Society.
,, Kõniglich Preussische Geologische Landesanstalt.
,, Royal Prussian Academy of Science.
,, Royal Prussian Geological Institute.
BOLOGNA.—Royal Academy of Sciences.
BOMBAY.—Bombay Branch of the Royal Asiatic Society.
,, Marine Survey of India.
,, Meteorological Department.
,, Natural History Society.
BORDEAUX.—Linnean Society of Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Queensland Branch, Royal Geographical Society of Australasia.
,, Queensland Museum.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Geographical Society of Belgium.
,, Royal Malacological Society of Belgium.
BUDAPEST.—Hungarian National Museum.
BUENOS AIRES.—Argentine Republic.
CAEN.—Linnean Society of Normandy.
CALCUTTA.—Archæological Survey.
,, Asiatic Society of Bengal.
,, Editor, "The Indian Engineer."
,, ,, "Indian Engineering."
,, Indian Association for the Cultivation of Science.
,, Indian Museum.
,, Meteorological Department, Government of India.
,, Survey of India.
,, University of Calcutta.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Royal Mineralogy (Geology) and Pre-Historic Museum of Dresden.

CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
DRESDEN.—Isis Society.
DUBLIN.—Royal Dublin Society.
,, Royal Irish Academy.
EDINBURGH.—Geological Society.
,, Royal Scottish Society of Arts.
,, Royal Society.
,, Scottish Geographical Society.
,, Signet Library.
FLORENCE.—Royal Geological Commission, Italy.
GENEVA.—Société de Physique.
GLASGOW.—Geological Society.
,, Glasgow University.
GOTHA.—Editor, Petermann's Geographische Mittheilungen.
GÖTTINGEN.—Royal Society.
HALLE.—Kais, Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
HARRISBURG.—Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Vandois Society of Natural Sciences.
LEIDEN.—École Polytechnique de Delft.
LEIPZIG.—Vereinfür Erdkunde (Geog. Society).
LIEGE.—Geological Society of Belgium.
LISBON.—Geological Survey of Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Museum (Natural History).
,, Geological Society.
,, Iron and Steel Institute.
,, Linnean Society of London.
,, Royal Geographical Society.
,, Royal Institute of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
MADRAS —Forest Department.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
,, Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
,, Premier, Natural History, Victoria.
MILANO.—Italian Society of Natural Sciences.
MONTREAL AND OTTAWA.—Geological and Natural History Survey of Canada.

MONTREAL AND OTTAWA.—Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NAPLES.—Royal Academy of Science.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Sciences.
,, The Editor of the "American Journal of Science."
NEW YORK.—Academy of Sciences.
OXFORD.—University Museum.
PARIS.—Geographical Society.
,, Geological Society of France.
,, Geological Survey of France.
,, Mining Department.
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
QUEBEC.—Literary and Historical Society.
RIO-DE-JANEIRO.—National Museum.
ROME.—Geological Survey of Italy.
,, Royal Academy.
SACRAMENTO.—Californian State Mining Bureau.
SAINT PETERSBURG.—Geological Commission of the Russian Empire.
,, Imperial Academy of Sciences.
SALEM.—American Association for the Advancement of Science.
,, Essex Institute.
SAN FRANCISCO.—Californian Academy of Sciences.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
STRASBURG.—Strasburg University.
SYDNEY.—Australian Museum.
,, Department of Mines, New South Wales.
,, Geological Survey of New South Wales.
,, Linnean Society of New South Wales.
,, Royal Society of New South Wales.
TOKYO.—Asiatic Society of Japan.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Geological Institute.
,, Imperial Natural History Museum.
,, K. K. Geographischen Gesellschaft.
,, Royal Academy of Science.
WASHINGTON.—Smithsonian Institution.
,, United States Department of Agriculture.
,, United States Geological Survey.
,, United States Mint.

WASHINGTON.—United States National Museum.
WELLINGTON.—Colonial Museum and Geological Survey of New Zealand.
,, Department of Mines, New Zealand.
,, New Zealand Institute.
YOKOHAMA.—German Naturalists' Society.
,, Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.

The Governments of Bombay, India, Madras, North-Western Provinces and Oudh, and Punjab.

The Chief Commissioner of Burma.

The Resident at Hyderabad.

Report *on the* Geology *of* Thal Chotiáli *and part of the* Mari country, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a map and 5 plates.)

Area to be described.

The area to be described in the following paper lies to the east of that treated of last year; its limits can be seen by reference to the map annexed.

Previous literature.

Apart from the very brief mention of the gorge at Tung by Dr. Blanford,[1] and some papers regarding the petroleum at Khattan which have been referred to in my previous report,[2] there is no literature regarding the area under description.

Structure.
Absence of great faults.

The structure presents the same features as were noticed before, in the almost complete absence of any of those great reversed faults and thrust planes which are so common in mountain regions. The only exception is in the south-east corner, where, according to Sub-Assistant Hira Lal, the upper nummulitic beds and cretaceous beds are faulted into direct contact with each other. But, though not exhibited on a large scale, there are many very pretty instances of faults on a small scale, two of which are shown in Plates I and II.

Horizontal beds.

A very remarkable occurrence of horizontal beds over a considerable area in the Béji valley was quite unexpected in a region usually so highly disturbed. The horizontality is made very conspicuous in the field, and easily recognizable on the map, by the capping of hard Spintangi limestones crowning the hills of Gházij shales and exhibiting those long horizontal lines of cliff and talus slopes, with an irregular outline cut by numerous re-entering angles, which form the scenery characteristic of a deeply eroded series of horizontal beds of unequal hardness.

Stratigraphy.
Oldest rock seen: massive limestone.

The oldest rock exposed is the same grey limestone as was seen in the Miráb Tangi,[3] but it was much better seen this year in the hills west of the Thal Chotiali plain, which are traversed by the Sémbar pass. The beds are thrown into an anticlinal fold, whose core, composed of these hard grey limestones, stands up as a high hill, traversed by the deep gorge of the Sémbar pass.

This gorge is not of the ordinary type of water-worn ravine, exhibiting on either side a section of the beds through which it is cut, but has been formed along a deep and sharply-folded synclinal flexture, which obliquely traverses the main anticlinal. The stream has taken advantage of the narrow strip of soft beds, which was thus made to traverse the hard limestone core, and has deprived us of the deep cut section which this pass should otherwise have exhibited.

About 3 miles to the west, however, there is a gorge cut through a lower part of the hill which exposes a section of a portion of the limestone, and exhibits it as very similar in type to the cretaceous grey limestones of the Quetta hills, with which I have little doubt that it is identical.

[1] Mem., Geol. Surv., Ind., XX, p. 197.

[2] Rec., Geol. Surv., Ind., XXII, p. 93.

[3] Rec. Geol. Surv. Ind., XXII, p. 93; the word 'nummulitic' in the marginal reference is an error.

Distribution.

This limestone crops out in the centre of the Dunghan mountain, of the anticlinals of Samach, of the Miri hill, and of Mazár Diik in the Béji valley. Though not mapped as occurring in the Rastaiáni hill, east of Mámand, it appears to occur there, so far as can be judged from the account of Sub-Assistant Hira Lal.

Fossils.

From none of these last named localities were any fossils obtained, but in the Sémbar pass the uppermost beds yielded some fossils, among which a *Rhynconella* was most abundant. A fragment of an ammonite was also found, and *Belemnites*, which appeared to belong to the same species as occurred in the next succeeding group, but they had been shattered by the disturbance the beds had undergone, and could only be extracted in a fragmentary condition which precludes any specific determination.

Belemnite beds.

The massive cretaceous limestones are overlaid with perfect conformity by a series of beds which, in the Sémbar pass, attains a thickness of at least 1,000 feet, but is usually much thinner, the difference being apparently due principally to a squeezing out of the lower shaly beds by compression. In the Sémbar pass the lower half of the group is composed of black shales with some sandy and calcareous beds and, near their base, the shales contain an admixture of volcanic ash. The upper half of the group consists of distinctly bedded green and purple indurated marls and limestones, capped by about 250 feet of compact white limestone.

Equivalent to Chappar shales.

These upper beds resemble so closely, in lithological character, those variegated beds seen in the Chappar rift, which were formerly[1] referred to by me as the Chappar shales, that I have no hesitation in identifying the two. They agree, moreover, in stratigraphical position, as will be seen further on, and the occurrence of an admixture of volcanic ash with the sedimentary material of the lower beds in the Tarai Tangi[2] is another fact pointing to the same conclusion; moreover, there are frequent exposures of precisely similar beds occupying the same position relative to the other rock groups in the ground intervening between the Sembar pass and the Chappar rift.

Having established the identity of the group in the two separate localities, it appears inconvenient that it should retain a name derived from a locality where it is very imperfectly exposed, neither the thick white limestone at the top, nor the still thicker black shales at the base being represented, except in a most imperfect manner, and I shall in future refer to the group as the 'belemnite beds.'

Fossils, belemnites, ammonites.

These belemnite beds are, in many places, abundantly fossiliferous, but the fossils found are almost entirely confined to several species of *Belemnites*, mostly belonging to the section *Dilatati*, the only exceptions being a few fragmentary casts of *Ammonites* found 3 miles west of the Sembar pass.

Nummulites.

The uppermost white limestone was not observed to be fossiliferous within the area of the map, except for a few belemnites near its base, but I have seen it, on the road from Harnai to Loralai, containing both *Nummulina* and *Alveolina*. At the time I was not aware of the true stratigraphical relations of the rock, and, being inclined to class it with the overlying

[1] Rec., Geol. Surv., Ind., XXIII, 93 (1890).
[2] *loc. cit.*, p. 94.

Dunghan limestone, then regarded as nummulitic, did not attach the importance to the observation which it has since proved to possess, and, unfortunately, did not carry off any specimens. There can, however, be no doubt as to the accuracy of the observation.

Distribution.

The distribution of the belemnite beds is wider than that of the underlying massive limestone. Besides forming an oval round all the exposures of the latter, it is the lowest rock exposed in the Sonári anticlinal and in two others in the south-east corner of the map; to the north of Lat. 30° it is the lowest rock seen in the cores of the anticlinals; and is known to be largely exposed to the north of the map in the direction of the Bóri valley.

The distribution of fossils in this group appears, at first sight, to be capricious, for they have only been found in the Sémbar, Samach, Mazár Drik, Dunghan and Miri anticlinals, and not in those to the north-west or south-east of these. This is, however, probably due to the fact that, in those exposures where no fossils have been found, only the uppermost beds are exposed, and these are everywhere very sparingly fossiliferous, if fossiliferous at all. Further to the north, along the Bóri-Mékhtar road, belemnites are common enough in the beds of this group.

Unconformable break.

The belemnite beds form the uppermost member of a conformable system, above which comes a slight, but distinct, unconformable break. This is best seen in the Sonári anticlinal and that near Mazár Drik in the Béji valley, where the beds immediately overlying the white limestone contain numerous fragments of it; in the Mazár Drik anticlinal the white limestone is worn into an undulating surface, on which the lowest bed of the next succeeding system is deposited, and in the upper Béji valley there is a marine conglomerate bed containing fragments of white and grey limestone, the latter being apparently derived from the massive cretaceous limestone. This unconformity is also indicated by the remarkable variations in the thickness of the white limestone, variations which are equally noticeable outside the limits of the area under description. As has already been remarked, it has a thickness of about 250 feet in the Sémbar pass, but on north side of the Mazár Drik anticlinal this is reduced to only 20 to 30 feet. So, too, on the road from Harnai to Loralai there is no distinct band of white limestone seen in the first anticlinal crossed by the Miráb Tangi, between Harnai and Tarwe Khan, but, at Dilkúna, only 5 miles further on, the white limestone is well developed, though the thickness was not estimated.

Another fact, pointing to an unconformity between the belemnite beds and those overlying them, is the occurrence of pebbles of white nummuliferous limestone, evidently derived from the uppermost white limestone of the belemnite beds, in a conglomerate which occurs near the top of the Gházij group both near Shahrig and to the south-east of Quetta.

Unaccompanied by disturbance.

But, although this unconformity is distinct and unmistakeable, there is not, so far as I have yet seen, any recognizable divergence from a perfect parallelism of dip between the beds above and below it. It was not, consequently, preceded by any marked disturbance of the beds already formed, and need not represent very great lapse of time. On the other hand, if the identification of the pebbles of grey limestone in the lower beds of the next succeeding system with the massive cretaceous grey limestone, is correct, there must have been a very extensive denudation, meaning a

considerable lapse of time, and the absence of any of the *Belemnites*, so abundant immediately below the unconformity, in the overlying beds points to the same conclusion. For the present, however, and until the results of more extended survey are available, it is impossible to determine the exact stratigraphical value of this unconformity.

Dunghan group.

The group which is met with immediately above this unconformity is, in many ways, the most interesting of all those met with; it is the same that was described by me as the Dunghan group. In the northern part of the area surveyed during the past season it presents the same character as it has in the Harnai district, that is to say, it is essentially a limestone group of great thickness. To the south a remarkable change comes in by the development of argillaceous beds in the base of the group, which encroach more and more on the limestone till, in the south-east, only a few of the uppermost beds remain as limestone, the rest of the group being mainly argillaceous with some subsidiary beds of sandstone and impure limestone. The limit of the change between the two facies is tolerably well defined, coinciding approximately with the road from Spintangi to Thal Chotiáli; and its abruptness is noteworthy. Thus, in the Dunghan mountain, the group is composed of limestones, some 2,000 feet in thickness, but within 15 miles to the east, in the Mazár Drik anticlinal and to the south-east in Sonári, there is not more than two or three hundred feet of limestone at the top of a thick series of shales.

Change of facies.

It is natural to ask whether such a sudden change of facies does not indicate a distinction between the two; such at first was the interpretation I was inclined to put upon it, and in the field maps the distinction was preserved to the last. A gradually increasing intimacy with their mode of occurrence, and a careful review of the evidence, has, however, convinced me that they are identical, in spite of their lithological dissimilarity.

Dés valley.

A very good exposure of the argillaceous facies of this group is seen in the Dés valley near Khattan. In the lower portion of this tributary valley the Gházij shales are seen, which continue till a sheer sloping face is met with, composed of the pseudo conglomerate or true limestone breccia,[1] associated with flaggy limestone as at Khattan, the total thickness being about 100 to 150 feet. This is underlaid by 600 to 700 feet of grey shales, below which comes a group of beds which forms a well marked and easily recognizable horizon in all the sections of this district. The uppermost bed is a limestone, composed almost entirely of oysters (*Exogyra ?*), but also containing a few other fossils. In the section it is very dark coloured and impregnated with petroleum, which oozes from the exposed surface. This is underlaid by sandy beds, one band of which is red throughout, and the others frequently stained red with iron. Below the sandstones, in the Dés valley, comes a great thickness, probably over 1,000 feet, of shales, many beds of which are so abundantly fossiliferous as to become impure limestones. At the head of the valley, where the dip flattens down horizontal, they form cliffs surrounding an amphitheatre, and are conformably underlaid by unfossiliferous grey, green, and purplish shales. The limit between the profusely fossiliferous beds and those in which no fossils can be found is abrupt, but perfectly conformable, and

[1] Rec., Geol. Surv., Ind. XXIII, pp. 94, 95.

though no fossils are as a rule to be found in the shales, yet, in the Mazár Drik anticlinal, I found, low down in this portion of the group, a band of *Nummulites*, apparently identical with some of the forms found higher up.

The band of sandstones, stained with iron, and overlying oyster bed, can be recognized in all the sections in the southern part of the area included in the map and is important in the identification of this shaly group with the Dunghan limestone, for, in the Mazár Drik anticlinal, the whole thickness of the beds above it consists of limestones, which there is no difficulty in recognizing as the same as the unmistakeable Dunghan limestone close by. But the identification of the shaly group with the Dunghan depends mainly on the similarity of stratigraphical position of the two and the constant presence of the pseudo conglomerate. or limestone breccia, at the top of the group marking division from the overlying Gházij shales.

This bed forms well-marked and easily recognizable horizon throughout the area surveyed; it is almost invariably visible, where the Dunghan group is shaly in composition with only a small thickness of limestone at the top, and is frequently visible in the northern part of the area, where the group is composed of limestone throughout. How far its local absence may be due to imperfect action of the causes which led to the concretionary structure being developed, and how far to imperfect exposures of the bed, it is not altogether possible to say, but it is noteworthy that, in the northern portion of the area under description, the concretionary structure is less well-developed, and here the observed occurrences are least frequent, while in the south and east, where there is hardly a contact section in which it cannot be detected, the concretionary structure is so well developed that it is frequently almost impossible to believe that it is not a true conglomerate. I have, however, no reason for departing from the conclusion come to last year regarding the nature of this structure, and, in spite of the very striking appearance presented by individual exposures, there are several features in its mode of occurrence which are incompatible with the supposition that it is a true conglomerate; these are, the absence of any important variations in thickness, its interstratification with fine grained flaggy limestones, the absence of any coarse grained deposits associated with it, and, above all, the absence of any rock, of older date, similar to that of which the "pebbles" are formed.

The presence of this peculiar and easily recognizable rock at a definite horizon has been a most important aid to the geological mapping of the country, as it enabled the boundary between the Dunghan and Gházij groups to be determined with accuracy, when this would, in its absence, have proved almost impossible of accomplishment.

Fossils.

Concurrently with the change of facies of the Dunghan group it becomes abundantly fossiliferous, and a large number of specimens were obtained from the shaly beds. When the fauna of this group comes to be examined in detail, I anticipate it will lead to results as striking in their way as the remarkable change which, within twenty miles, converts a group of marine limestones, 2,000 feet in thickness, into an almost entirely argillaceous group. Until the fossils collected have been examined by a competent palæontologist it would be presumptuous to hazard an opinion as to the palæontological affinity of the fauna as a whole, but it presents certain striking anomalies which cannot be passed over in silence.

Anomalous fauna.

Among the *Cephalopoda* collected were fragments of two species of *Ammonites*, *Crioceras*, and besides these I have been shown *Ceratites* and *Baculites*, which were found by Mr. R. A. Townsend in the Dés valley; among the echinodermata fully half the specimens found belong to the order *Echinoconidæ*, and an oyster very like *O. carinata* is not uncommon. These would ordinarily be held sufficient to stamp the fauna as cretaceous, or at any rate upper secondary, yet this fauna not only occurs above the white limestone of the belemnite beds, in which *Nummulina* occur, but is accompanied in the same group by an abundance of specimens of *Nummulina* belonging to three or four species. I am aware that the genus *Nummulina* has been found in beds of carboniferous and of secondary age, but it is uncommon and, as yet, it has always been accepted that any beds in which the genus is abundantly represented are of tertiary age.

Under these circumstances it must remain an open question whether we are to regard the Dunghan group as oldest tertiary, or newest secondary, in age. Dr. Blanford in his memoir [1] regarded the Dunghan limestone, near Harnai, as lower nummulitic, and very naturally so, for the almost only recognizable fossils it contains are foraminifera, mostly *Nummulina*, but in the Suleiman hills he took the "limestone breccia" to mark the base of the tertiary system. As may be seen from what I said above, there is a contradiction here and, as matters stand, it is impossible to say which of the two views is correct. If the top of the Dunghan group represents the lower limit of the tertiaries, we have to acknowledge an extreme abundance of the genus *Nummulina* in beds of cretaceous age; if the bottom, then the *Ammonoidea* are represented, in beds of tertiary age, by several genera and species. A third interpretation is open, and probably it will prove the true one, that the Dunghan group represents the gap between the Secondary and Tertiary period in Europe.

Distribution.

The distribution of the Dunghan group is a large one, and is best explained by a reference to the map. In the north-western portion of the area, where it consists mainly of limestone, it forms high hills and mountains; to the south-east, where it is shaly, this is much less noticeable as, in most cases, the thin shell of limestone has been broken through by denudation, and the easily removed shales exposed.

Gházij group.

The Dunghan group is conformably overlaid by the Gházij group which presents the same character as was described in my previous paper and will not require lengthy notice here. To the north of the Thal Chotiáli plain some coal seams occur in this group, and near Khattan a thin band of impure coal is found near the top of it, but throughout the rest of the large area it occupies no coal was seen. Fossils are not very abundant except near the top of the group.

Spintangi group.

The Gházij group is overlaid by the Spintangi beds, not only with most perfect conformity, but with an absolute obliteration of any definite boundary. In the neighbourhood of Khattan several thin beds of white limestone, of the Spintangi type, occur among the Gházij shales, and green shales are found interbedded with beds which appear to be the equivalents of the Spintangi group at Spintangi. It has become evident that the lithological discrimination of the two groups is impossible, and, on palæontological grounds, it will

[1] Memo., Geol. Surv., Ind., XX.

be equally difficult, for the fauna of the shaly beds is not extensive, and naturally is very different from that of the clear limestones, and the same fossils, at least so far as the more abundant forms are concerned, appear to be common to the limestone bands in the Gházij groups and to the main body of the overlying Spintangi group. Under

Want of definite boundary.

these circumstances, seeing what a large share the mere change of condition would have in bringing about the change of fauna, a line of demarcation drawn on palæontological grounds would no more represent a definite epoch than one drawn on purely lithological grounds. In fact there is no real distinction between the groups, and there is good reason for supposing that, to the south-east of the limits of the map, beds would be mapped as Spintangi which were of contemporaneous origin with some that have so far been mapped as Gházij.

Although the boundary between these two groups has none of that definiteness which attaches to the other boundaries, it has been inserted as a matter of convenience, for not only does the sub-division of the nummulitic beds above the Dunghan serve to render the structure of the country recognizable at a glance, but it serves to show to the distribution of two strongly contrasting types of deposit.

A noteworthy feature of the Spintangi beds in the southern portion of the area mapped is the thickness of the gypsum beds it contains. Along the upper part of the Khattan valley they are very conspicuous on the scarps, and near Mámand there is, according to Sub-Assistant Hira Lal, a bed of 50 feet thick, besides four others aggregating 33 feet in a total thickness of about 400 feet near the middle of the visible section of the group.

Siwalik.

The Spingtangi group is overlaid to the south by Siwalik beds of the ordinary type, and these are the only indubitable Siwaliks in the area examined. There are, however, some other beds whose true classification it is difficult to determine; from their aspect they might well pass for Siwaliks, but as it is very doubtful if they are contemporaneous or were ever continuous with any of those beds which have been mapped as Siwalik along the margin of the hills, I prefer to class them separately for the present.

Sub-recent gravels of Mámand.

The most important of these is an area of disturbed sands and gravels lying east of Mámand. They consist mainly of old river shingles, but, where they have been cut into, these are found to be interbedded with soft sandstone, little harder than rock-sand, and clayey beds; they have mostly a distinct dip which in one place rises to 50°. Besides this main exposure there are three outliers, perched on the top of hills, at the eastern end of the Mámand plain. These gravels are evidently old deposits of the same stream which now flows to the south of Mámand; but, since they were formed, there has been some disturbance of the beds and an alteration of the course of the drainage, partly due to this disturbance, and partly to a lowering of levels along the band of easily denuded Gházij shales, a little way to the south.

Further down this stream, near Karmari, there is a large development of gravel deposits which rarely show any noticeable disturbance, but have been deeply cut into by the streams.

Béji valley.

In the Béji valley there is a large expanse of gravel deposits in which no signs of disturbance were seen. They have, however, been cut into, to a depth of nearly 100 feet in places, and, just above the

junction of the Bareli, there is a hill of Gházij shale, capped by sub-recent river gravels.

Thal Chotiáli.

In the Thal Chotiáli plain, separating the main area from the Karáhi plain, there are some low hills of gravels, which have been bent up into an anticlinal. These are evidently old deposits of the river, before its gradient was checked, and have since been disturbed. They will be again referred to when treating of the Thal Chotiáli plain.

Disturbance of gravels at Panuṇ.

The most remarkable instance of disturbance of these sub-recent river gravels is exhibited by those of the Panuṇ valley (Pano of the map). Between the Sherki hill and the western end of the Mazár Drik anticlinal there is a great thickness of gravels, through which the stream has cut its way. At their northern limit these are in direct contact with Gházij shales, and have been bent up vertical and in places as much as 30° beyond the vertical, so as to acquire an apparent dip to N. at 60° (Plate III). The dip is very local; within 300 yards to the south it has almost disappeared, and, throughout the area occupied by these gravels, no signs of disturbance were seen, except in the immediate vicinity of its northern margin.

Recent gravels and alluvium.

Gravels of recent date are abundant in all the stream valleys. They have not been considered of sufficient importance to be mapped in detail. Besides the numerous smaller deposits in the stream valleys there is a large area in the Quat Mandai valley, covered principally by gravels, but in part also by fine-grained alluvial deposits.

Landslips.

Among recent deposits must be classed landslips, which are more common than would be expected in so dry a climate. There is a very large and conspicuous landslip at Kuriák Tangi, 8 miles east of Spintangi, which extends for nearly 3 miles across the valley, having come from the hills to the south. This landslip must have blocked the drainage for a time, as the Tangi is cut through its substance, between its source of origin and termination.

Smaller landslips are common where the Gházij shales are exposed on a hillside, being induced by the manner in which these shales weather into slimy mud which will move over very small gradients. A very striking instance occurs south of Sonári, where, on the watershed between the drainage of the Chákar and Béji valleys, the whole outcrop of the Gházij shales is completely concealed by a thick layer of huge angular masses of Dunghan limestone. It is, at first sight, almost impossible to suppose that the limestone is not *in situ* here, but, on either side of the ridge, these blocks are seen to overlie the edges of nearly vertical beds of the Dunghan and Spintangi groups.

Alluvial and loess plains.

The most interesting and important of the recent deposits are, however, the numerous valley plains of fine-grained loess or alluvium. These vary in size from the numerous small "Thals" on the hillsides, too small to be distinguished on the map, to the great plain of Thal Chotiali, and the still greater plain of the Sibi "Pat."

The Thals are small hollows, perched about the hillsides and on the hill tops, some due to solution of the underlying limestone, others to small landslips, in which accumulations of dust and rain wash, from the surrounding hillsides, form a very gently sloping floor. They are mostly cultivated by the Maris, who have not yet been

able to get over the objection, born in old predatory days, to cultivating the valleys, where the crops are visible to every passer-by, and would probably have been reaped by some other person than the man who sowed them.

The larger plains, those of Mámand, Samach, and Púr, as well as some of the smaller ones, evidently owe their origin to differential movements, or warping, of the surface, by which the drainage was checked, and the accumulation of fine grained deposits rendered possible.

Mámand.

The plains of Púr and Mámand are both situated in synclinal hollows of the underlying rock; in the latter case the old escape of the drainage can be traced on the south side of the plain, and the old river gravels, deposited in former times when the streams flowed across the area now covered by the plains, extend over a low divide and slope gently northwards under the loess. The deposit which fills the hollow that was formed is fine and uniform in grain, of a pale grey colour, and very calcareous; the very few and shallow sections exposed show no signs of stratification, and there seems no reason to doubt that it is, in the main, wind blown leess, derived from the dust blown off the surrounding hills, supplemented to some extent, near the margins of the plains, by matter brought in by the streams. The history of the plain is evidently as follows: At first there were river valleys of the ordinary sort draining to the south. After these had been well excavated, the compression to which these hills have been subjected caused the stream bed south of the Mámand plain to rise at a greater rate than the stream could cut down its channel. The first result of this was to form a deposit of gravel filling up the hollow, but the rise of the barrier went on at a greater rate than the deposit and a hollow was formed which the materials brought down by the stream could not fill and from which the dust that accumulated could not be washed away; so the loess gradually formed and by degrees spread over the gravels, hiding them and obliterating all minor inequalities of the ground to form a nearly level plain, now cultivated over almost the whole of its area. The whole of this process, from the original carving out of the valleys to the formation and filling up of the basin, every stage of which must have been very slow and gradual in its progress, has taken place since the deposition of the sub-recent gravels mentioned above, and, when it is remembered that these are among the latest members of the tertiary period, if indeed they are tertiary at all, it gives a most striking indication of the incomprehensibly vast periods of time which the geological record must necessarily cover.

Samach.

The Samach plain differs from that of Mámand in being formed on the crest of an anticlinal, but its origin is none the less evidently due to differential movements of the surface. Its history has been as follows: In the first instance an anticlinal hill of Dunghan limestone was formed, whose crest was broken through by denudation, exposing the easily denuded shales of the lower part of that group and the Belemnite beds, and a tolerably deep valley was consequently formed, but the drainage of this valley had to cross the axis of the anticlinal, and, in consequence of further compression, the ground along the axis rose and checked the drainage, after which the subsequent history was much the same as that of the Mámand plain.

The fine grained deposits of Samach differ somewhat from those of Mámand in appearance. Whether they are calcareous or not I forgot to note, but their colour is

a reddish brown, and they are much more loamy in appearance and texture. The difference is doubtless due to the amount of fine grained argillaceous matter washed down into this plain, whereas at Mámand the bulk of the debris brought down by the streams was limestone gravel, which came to rest close to the edge of the hills.

In the Samach plain we can see the beginning of the end, for the barrier has been partly cut through and the stream has cut back into the plain, converting its eastern end into a maze of perpendicular-sided ridges and channels, while the rest of the plain still preserves its original smooth surface.

Thal Chotiáli.

The other plains of loess present very much the same character and history as these and do not require further notice here, but the great Thal Chotiáli plain, 45 miles in length and 12 in breadth, presents so many features of interest that it cannot be passed over without some mention.

The western half of the plain is a barren treeless expanse of pale grey loess, at first sight level throughout, but having in fact slight gradients to the west and south, where water collects after heavy rain. In the eastern end the soil is of a reddish colour and is less of a dead level, some slight rises being perceptible, especially near Gumbaz; and along the banks of the stream, which flows past Gumbaz and Chotiáli, there is a park-like strip in which tamarisk and poplar trees shade the stream and are dotted about with green sward under their shade, forming a view not unpicturesque in itself, and positively beautiful by contrast with the barrenness of the surrounding country. The Karáhi plain, too, is in spring a mass of verdure. In March last its centre was occupied by an expanse of water in which numberless waterfowl and waders were disporting themselves, and on the stretch of ground surrounding it countless herds of sheep, cattle, goats, and donkeys were grazing.

The fine grained deposits of the plain are of two distinct types. One of these is pale grey in colour, highly calcareous and very obscurely stratified. It corresponds to the loess deposits of the Quetta plain. The other is of a reddish brown colour, imperfectly but distinctly stratified, which appears to correspond to the undisturbed equivalents of those beds which, in the Quetta district, have been classed as Siwalik.

The drainage of the plain presents features of interest. On the north two considerable streams enter the valley. One of these drains the Sinjáwi valley and flows past Dúki. The ordinary flow of this stream is entirely absorbed by cultivation and the flood waters spread out over the plain, partly soaking into it, partly accumulating in the hollows, whence they gradually disappear by percolation and evaporation.

The other is the Hanambár stream, which is joined near Chotiáli by the Naréchi flowing from the east, and the combined waters flow out through the hills at Tang, or, as it is more commonly called, the Gháti bridge, being there, and for the rest of their course to Babar Kach, known as the Béji river.

Present drainage outlet.

This, the only outlet for the drainage of the Thal Chotiáli plain, is not the original course of the drainage, and is, moreover, of very recent date. The hills on either side of it are low, and slope gently to the stream,[1] which does not flow in any deep cut gorge or steep-sided valley marking the long action of denudation. There are no traces of river gravels, and in the plain above the hills the stream flows in a narrow

[1] See Plate IV.

channel of 20 to 30 feet deep, from which two nullahs are cutting back on either side into the loess deposits along the foot of the hills. Everything marks the outlet as geologically of very recent origin. The stream bed, after entering the hills, is formed by deep, stagnant reaches, separated by small waterfalls or rapids, where the water flows over a steep slope of angular debris. The deepening of this channel must proceed slowly, for it can only take place through the power of the floods to tear angular masses of rock out of its bed, the waters having been deprived of all solid matter, too coarse to be carried in suspension, long before they cross the plain. This absence of pebbles borne along by the water has deprived the stream of much of its abrading power and the outlines of the stream bed, and of the loose fragments in it, are everywhere almost angular. Occasionally, however, they exhibit indistinctly the same sort of sculpturing as is seen on rocks exposed to the action of wind blown sand,[1] which is in this case caused by the fragments of sand carried along in suspension by the water.

Old course of the Béji.

After a course of a couple of miles, down what has all the appearance of the valley of a small tributary stream, as in fact it originally was, there is a broad open valley leading up to the west, and immediately beds of river shingle appear. Following up this side valley, it can easily be recognized as the old outlet of the river, which once gathered all the drainage of Thal Chotiáli. It is broad and open, and the Gházij shales, which are the rock *in situ*, are very little seen, owing to a cover of river gravels cut into by numerous small stream beds. The surface of this gravel deposit gradually rises to the west and ultimately forms a broad and almost imperceptible ridge at the eastern end of the Karáhi plain. The same gravels are seen in the ridge of low hills, which runs east and west, north of the Karáhi plain, where they are disturbed, forming in places the whole of the ridge, but, in others, only a skin over a central core of older rocks.

We have here the old course in which the Béji river flowed; its flow was checked by a rise of its bed along the anticlinal which runs south of the Karáhi plain, and finally closed by the rise of the ground at its eastern end. The formation of the low hills, separating this from the main area of the Thal Chotiáli plain, was of later date, and it is noteworthy that these hills lie along the continuation of a distinct anticlinal.

History of the plain.

The evidence that the compression and folding of the strata did not take place at one definite period and then cease, but that it has been a gradual process, going on concomitantly with the erosion of the river valleys, is peculiarly abundant in the Thal Chotiáli district, and it would be most interesting to work out the details with greater thoroughness than I was able to do on my somewhat hurried visit. We have first a certain amount of disturbance, the formation of a large drainage basin and extensive denudation. Then we have earth movements by which an area of closed drainage was formed and deposits accumulated; at a subsequent date a further movement caused the elevation of the low hills between Ismail Khan and the Karáhi plain, and, at a still later date, some of the fine grained loess deposits along the margin of the hills west of the Gháti bridge have been locally elevated and deeply cut into by the resulting erosion. Meanwhile the surface of the plain had gradually risen,

[1] See Records, Vol XXI, page 159.

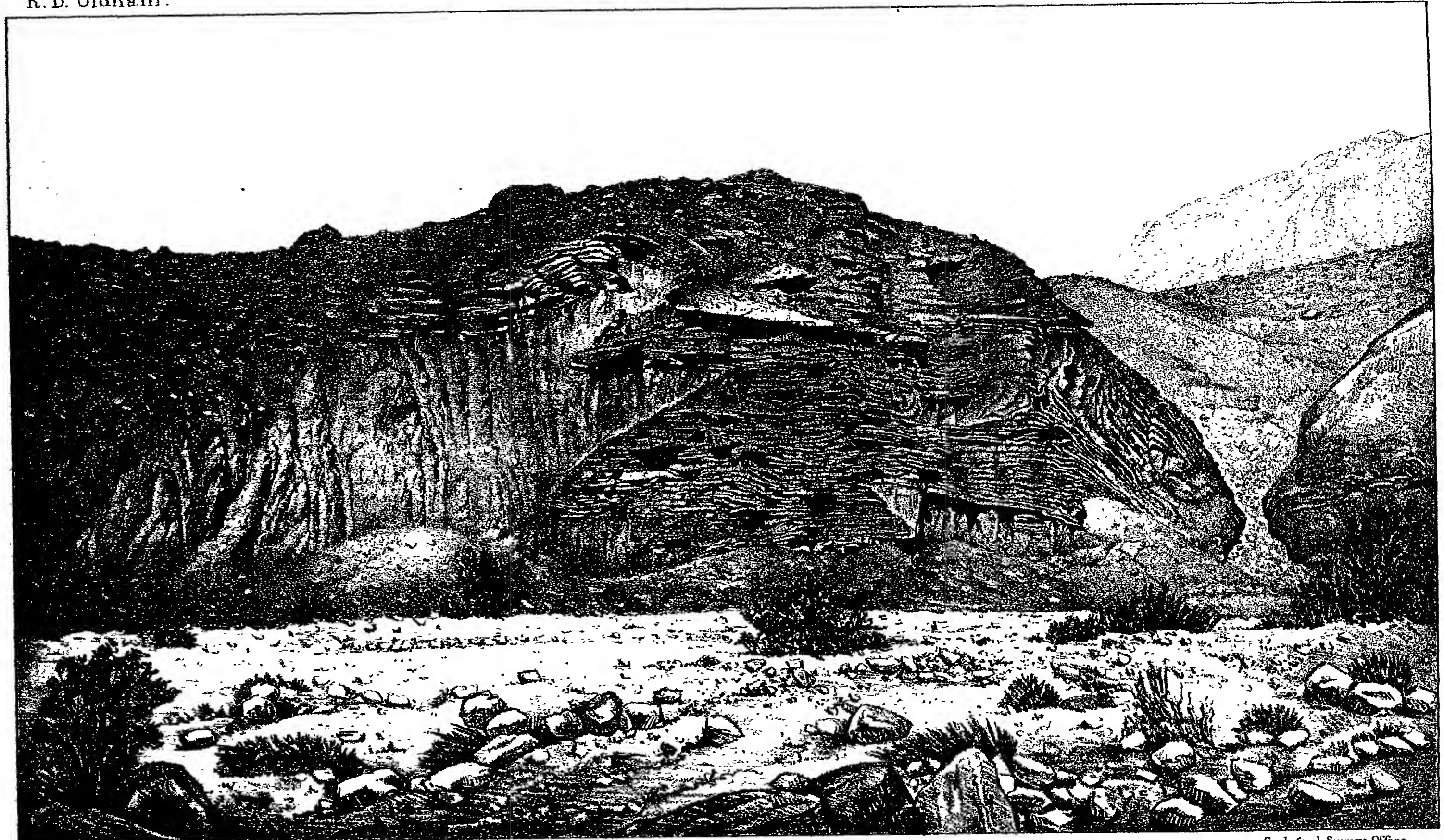

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PLATE. I. REVERSED FAULTING IN GHAZIJ BEDS NEAR THE DUNGHAN MOUNTAIN

R D Oldham

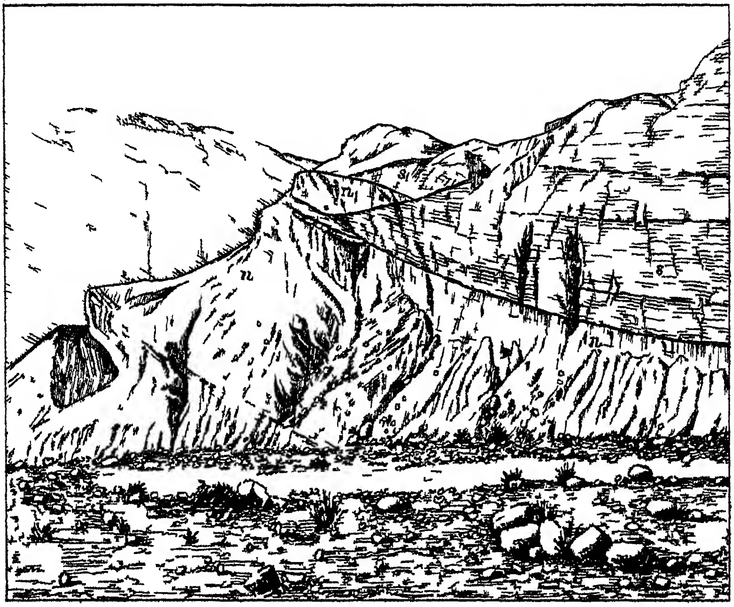

Fig I

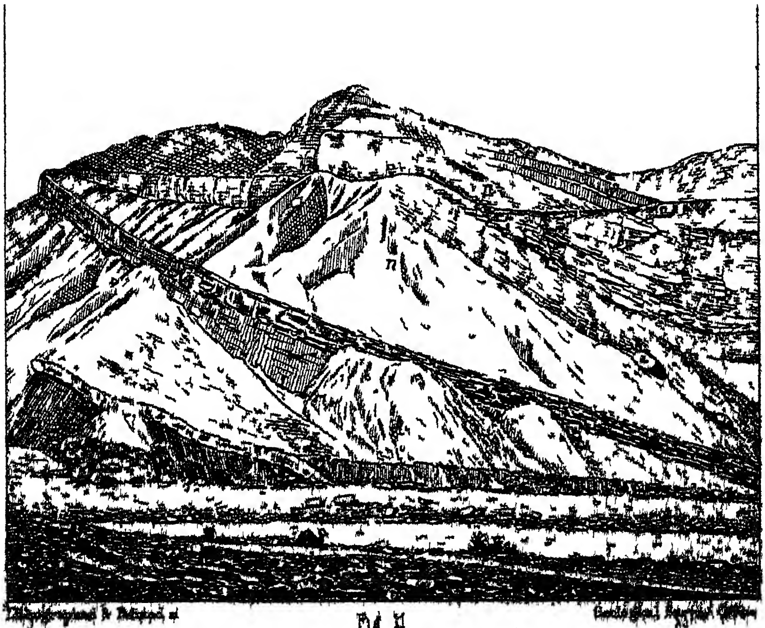

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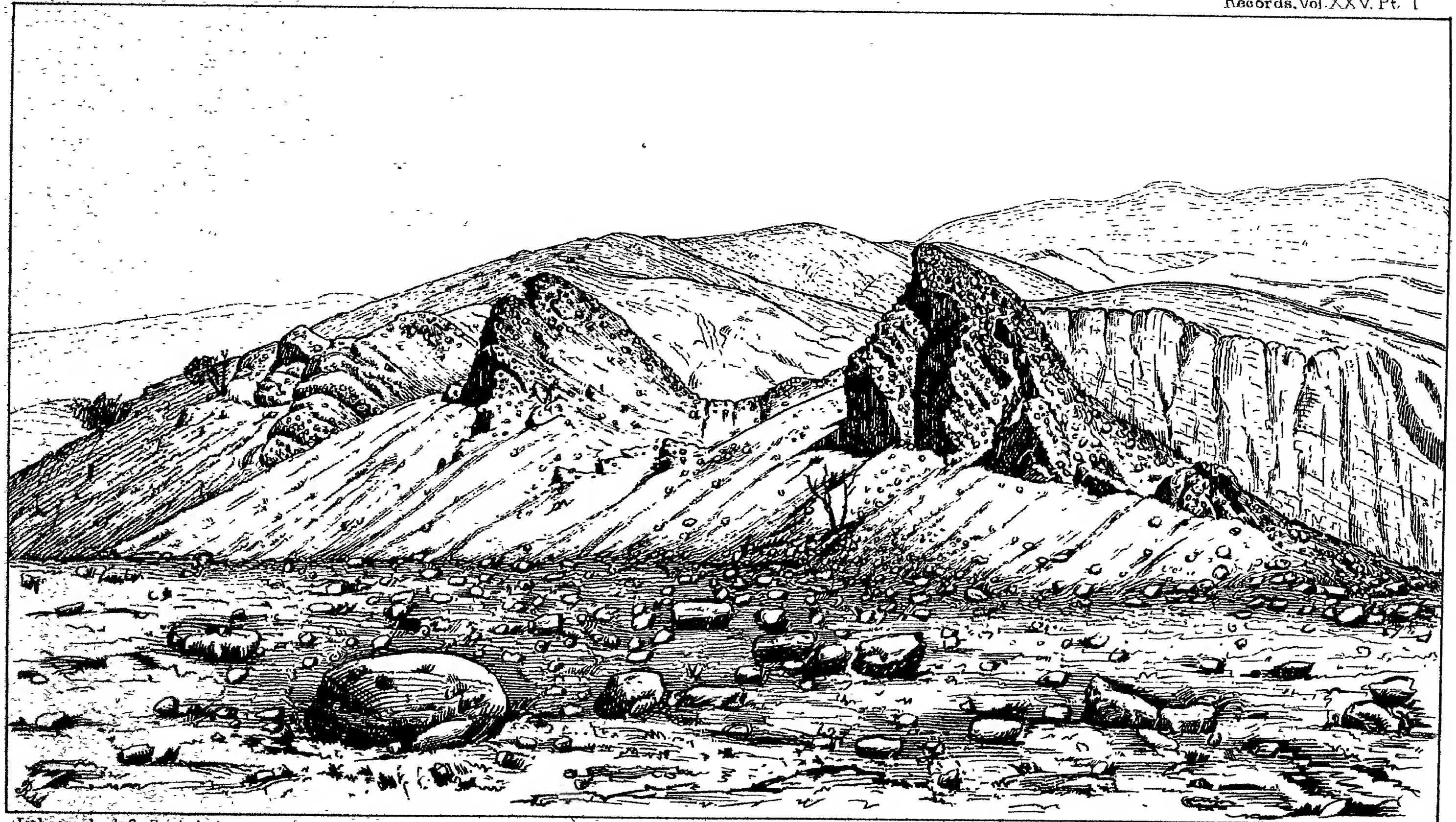
Fig II

PLATE II. JUNCTION OF NUMMULITICS & SIWALIKS ON ROAD TO KHATTAN, SHOWING SMALL THRUST PLANE

R. D. Oldham.



Lithographed & Printed at Geological Survey Office.

PLATE. III. DISTURBED RECENT RIVER GRAVELS AT PANUN

Lithographed & Printed at Geological Survey Office.

PLATE. IV. OUTLET OF BÉJI RIVER FROM THE THAL CHOTIALI PLAIN.

extending up a small tributary valley which originally flowed northwards past where the Gháti bridge now stands, till its level reached that of the divide. Some of the flood waters then flowed over this and, washing away the weathered and easily removable rock at the surface, established a defined channel, along which much of the drainage now escapes. Such are the main points in the history of the Thal Chotiáli plain.

Economic geology.

The economic results of the last season's work have been as disappointing as its purely geological results have been interesting.

Petroleum.

Traces of petroleum are widespread, and were found in the limestones of the Dunghan group at several spots throughout the area surveyed. It is most concentrated along the Khattan anticlinal. Old flows can be found in the Dés valley, and, in a corresponding valley, which drains the south side of the anticlinal. The shows are most abundant about the horizon of the red sandstone mentioned in the description of the Dunghan group. It is worthy of note that where this group is most profusely fossiliferous, most conspicuous signs of petroleum are found, and it is impossible not to hazard a guess that the coincidence is not accidental. As this petroleum has already been noticed in a previous paper[1] and been made the subject of a special report, I shall not enter further into the matter.

Coal.

Coal was found near Duki in several places, but the thickest seam seen only measured 14 inches, so it is not likely ever to be of importance. The distance from any centre of demand would very much detract from its value even if good seams existed.

Gypsum.

Gypsum was observed in great abundance and thick beds, one measuring 50 feet, near Mámand and in the Khattan valley; it will be long before it is worked for profit, though it is of excellent quality, and, if it could be easily got out, could be used for ornamental purposes.

Petrological Notes *on the* Boulder-bed *of the* Salt Range, Panjáb, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

INTRODUCTION.

The rock-formation known as the Boulder-bed of the Salt Range is one that has attracted much attention of late, as previous papers in the Records by Warth, Oldham, Blanford, Waagen, Medlicott, and myself during the last few years can testify. It is unnecessary here to do more than shortly re-state what has now been definitely established as regards its age and mode of formation. Instead of there being several crystalline boulder-beds at different horizons in the range, it has been abundantly proved that there is but one bed forming a bottom layer to the Speckled Sandstone stage and its eastern representative, and resting unconformably on the older palæo-

[1] Rec., Geol. Surv. Ind., XXIII, page 104 (1890).

zoic rocks beneath. From the great frequency of polished, striated and facetted boulders set in a clay or shaley matrix, and from the identity of these characters with such as are well known in pebbles of the boulder clay of *the* glacial epoch, it has now been generally accepted that the Salt Range Boulder-bed is a witness that glacial conditions prevailed over this part of the earth in palæozoic times. Furthermore, it is conjectured with reasonable probability that the (in many ways similar) bed in Peninsular India known as the Talchir is of the same age.

These facts and opinions being admitted, it occurred to me that a microscopical examination of the crystalline boulders, and a comparison of them with slices of rocks from the Maláni neighbourhood—the conjectured source of the boulders—might bring out some positive points of identity between the former and their supposed parent rock, whence they had been carried by the agency of ice. Although no specific identities have been established, I give the following account of the examination of a small set of typical samples of pebbles from the boulder-bed, in the hope that, ultimately, their actual source may be tracked down[1].

No. (1), $\frac{8}{467}$, 650. (*N.B.*—The first number in brackets is my own running number, the second is the registered number of the rock specimen, and the third the number of the microscope slide). In the hand specimen this boulder appears to be a coarse gneiss or gneissose-granite, roughly banded, and containing pinkish felspar, clear quartz, and muscovite. In a fairly large slice prepared for the microscope the gneissose structure is not noticeable. To whatever cause the banding of the rock be due, it may be remarked that it is of a different type from that usually found in the gneissose-granite of the Lower Himalaya. There is neither augen, lenticular-tabular, nor tabular structure, as in the latter.

The minerals present, in order of importance, are quartz, plagioclase, muscovite, biotite, magnetite, and apatite. In another section of the same rock Mr. Holland has recognised much pinite.

The quartz is present (1) in large grains composed of aggregates of distinct optical units. Magnetite and apatite are included in the quartz grains in small quantity. The usual minute inclusions forming dusty-looking lines traverse each grain, and there is also seen a fine parallel striation indicating zones of growth. With crossed nicols these dusty-looking lines of inclusions and the parallel striation are seen to pass without deflection through several of the optical units into which the grain then splits up. The individual units of this polysynthetic group are generally irregular in shape, but at the same time showing an approximation to a hexagonal outline. The distinctness of the units from an optical point of view and their material continuity, are shown in a rather thick section by the rainbow halo round each where it overlaps or is overlapped by its neighbour. (2) Quartz is also present along certain lines in the slice forming a finely granular mosaic with plagioclase and muscovite. These lines probably coincide with the macroscopical banding of the rock, and are due to crushing of the mass.

The polarization colours and extinctions of the optical units of the quartz aggregates are generally uniform in each unit; but locally a unit shows a watered colour

[1] My thanks are due to Messrs. P. Lake and T. H. Holland, of the Geological Survey, for supervising the cutting of the slices and for efforts to match them with rocks from Peninsular India.

(brilliant purple and azure blue, or pale lemon and deep ochre) with a slightly undulose extinction.

The felspar (1), like the quartz, occurs in large irregular grains, with a defined but irregular border next the large quartz grains, but with a ragged and intermingling border next the finely granular mosaic of quartz, felspar and mica. It is somewhat opaque, and generally includes many fine needles of apatite. It sometimes presents a sharp and fine twinning on the albite plan, and at other times broad and often irregular lamellæ which merge into each other insensibly. The ends of the twin lamellæ at the border of a felspar grain are often bent, sometimes spread out like the fingers of a hand, and sometimes completely ruptured. One felspar is ruptured along two lines crossing at right angles the twinned lamellæ, so that on each side of the lines of rupture they do not join properly. In this section of felspar also undulose extinction is prevalent. (2) The felspar is also present as a constituent of the granular mosaic.

The muscovite (1) is present in irregular packets of the usual kind in granites, but with slightly bent folia; (2) in the granular mosaic; and (3) as a cryptocrystalline aggregate in patches among the mosaic.

The biotite is only found in a small nest with cryptocrystalline structure.

The magnetite in minute proportions is dotted through the slice.

The apatite in minute characteristic highly refracting prisms and hexagonal sections is chiefly confined to the felspar.

This specimen resembles in a general sort of way No. $\frac{70}{50}$, 769 from Daolatgar Ajmir, but not sufficiently to make it probable that the boulder came from that locality.

No. (2) $\frac{8}{468}$, 651. In the hand this rock also is seen to be a coarse gneiss or gneissose-granite, but not so coarse as the last specimen. It possesses deep flesh-coloured felspar, much biotite, and the quartz is of a dark bluish grey tint. The banded appearance is fairly well seen.

In thin slice under the microscope the individual minerals are better seen and are as follows:—Quartz, felspar, biotite, magnetite, and sphene (?)

The quartz in this slide is in two or three irregular grains, but not so distinctly separated the one from the other as in the last section. As before, however, it is made up of a large number of optically distinct individuals, whose shapes, though sometimes inclined to be hexagonal, are more generally elongated in one direction into lens-shaped bodies, separated round their margins from each other by a very fine-grained mosaic of apparently powdered quartz. It is evident that differential movements of the particles of the original grains or layers of quartz have taken place along waving lines so that it has been sheared after the manner of the felspars and quartz in the microgranulitic rocks of Khairna described by me (Rec., G. S. of I., XXIII, pt. 1). In addition, every one of the optical units, when they are in the least lens-shaped or irregularly drawn out, show blurred colours with crossed nicols, and completely undulose extinctions. The general appearance then is not unlike that of 'marbled' paper. So far these lenticular and irregular optical units, with the very fine mosaic between them, are only well seen with crossed nicols, and the lines of minute inclusions pass uninterruptedly from one to the other. But there are still other parallel fissures and cracks filled in with secondary quartz or with powdered residuum from the original walls, and these can be seen quite plainly without the aid of polar-

ized light. Magnetite is enclosed in the quartz in small crystals and dusty grains, and so also are a few crystals of sphene (?). The extremely minute inclusions in the quartz throng the substance in swarms. They, together with the magnetic dust, may presumably be the cause of the blue colour of the quartz, so noticeable in the hand specimen.

The felspar is in very irregular grains and throughout the slide is generally altered into a finely granular aggregate, among which patches of small size in the body of the felspar, and of larger size at the margins, remain unaltered. The unaltered parts show a very fine lamellar structure as if the result of twinning. Sometimes it displays the 'plaided' appearance of microcline. Lines of differential movement, which have been remarked in connection with the quartz, are also observable in the bending and waving of the felspar lamellæ. Undulose extinction is also prevalent.

The biotite is in irregular layers, and markedly illustrates the mechanical deformation of the rock.

Magnetite is sparsely disseminated through the slice in small grains and crystals.

No. (3), $\frac{8}{469}$, 652. Macroscopically it is a coarsely granitic or gneissose rock, mottled red and black. Only a faintly linear arrangement of the minerals is visible.

Under the microscope the slide appears as a finely granular intergrowth of quartz and felspar grains, sometimes becoming regularly micropegmatitic, among which larger idiomorphic crystals of felspar, sometimes with well-preserved outlines, are thickly strewn

The felspar is by far the most largely represented in this slice, and it has some very complicated characteristics. (1) It occurs in rather large crystals, the crystallographic outlines of many of which are fairly distinct. The central portions of these are much darker than the outer zones. Other less distinct indications of growth zones can also be seen. Several of these felspars appear to be untwinned. They extinguish light at once and completely, without any banded polysynthetic twinning coming into view. Others show a very faint striation, which becomes just visible when the point of maximum extinction of the section as a whole has been reached in revolving the stage of the microscope. Others again show a very fine sharp lamellar twinning, and others the ordinary aspect of microcline. (2) Felspar also occurs in small micro-crystals irregularly scattered as inclusions in the former. (3) It also occurs in a sort of micro-granulitic ground-mass between the larger constituents of the rock. (4) It is associated with quartz in an ill-defined micropegmatite.

The quartz is present (1) in large grains often marginally passing into (2) micropegmatite; also (3) in smaller grains as inclusions in the larger minerals; and (4) in the micro-granulitic ground-mass.

A badly preserved green mineral in small quantities in nests is present.

Magnetite and apatite are also represented.

The whole rock is very much confused, but it does not suggest any form of mechanical deformation. I should be much puzzled to specifically classify it.

No. (4), $\frac{8}{470}$, 653. In the hand this appears as a fine-grained granitic rock of reddish brown colour.

Under the microscope the slide reveals a medium-grained granitic rock, composed of larger grains of quartz dotted about irregularly in a slightly finer ground-mass which is composed of smaller grains of quartz and microcline, with a little plagioclase and a green mineral, hornblende (?)

The microcline is in places intergrown with the quartz but in an irregular way, the structure merging into an ophitic structure, wherein plates of microcline include small quartz grains.

Small portions of a green mineral, probably hornblende, are seen, much disfigured by alteration and deposition of oxide of iron, which has spread about in between the other constituents of the rock in the neighbourhood.

In many parts of the slide original magnetite is disseminated in small well-formed crystals.

The whole rock has a very pellucid and defined appearance, and, with the exception of the green mineral, has suffered but little alteration, nor are there any evidences of dynamic metamorphism.

No. (5), $\frac{8}{471}$, 654. The hand specimen is a dark purplish-grey, compact rock, with large, somewhat eye-shaped porphyritic crystals of flesh-coloured felspar. It contains inclusions of a dark compact probably hornblendic rock.

Microscopically it appears as a typical micro-granulitic rock, containing porphyritically developed (1) large rounded grains of quartz of uniform crystalline structure; (2) felspars altered in many places, but possessing finely-twinned lamellæ such as characterize plagioclase and also broader twins of another kind superposed. One section of felspar exhibits a simple binary twin.

There are a few patches of ill-defined greenish mineral, which has apparently suffered much alteration.

The micro-granulitic ground-mass is in many parts minutely micropegmatitic. The quartz of the ground-mass can be picked out in ordinary light from the felspar, which is slightly yellowish grey in colour. In this light the micropegmatite can be seen very distinctly, and it appears to constitute a considerable portion of the ground-mass. It seems at first sight that the intergrowth of the quartz and felspar has taken place at innumerable centres in the ground-mass, separately, and not uniformly, over large spaces.

Magnetite is present in small quantity in minute crystals and crystalline aggregates.

No (6), $\frac{9}{472}$, 655. This rock is of common occurrence and may be said to characterize the Boulder-bed. It appears in the hand as a fine-grained, flesh-red granophyre, with blebs of blue quartz and hornblende in small quantities.

Under the microscope it appears as a beautiful micropegmatite, with quartz and felspar porphyritically developed.

The micropegmatitic structure is very distinct and extremely beautiful. By ordinary light the pellucid quartz is visible in uniform, or triangular individuals with truncated apices, and ranged in lines or in more or less vermicular and parallel streaks converging towards centres, lines or round porphyritic quartz and felspar crystals. There is thus a faint tendency to what is known as centric structure. The clear quartz individuals, thus arranged, appear inlaid in a pale yellowish-grey matrix, the latter being altered felspar, which still retains considerable power of lightening and darkening uniformly between crossed nicols. The whole of this micropegmatitic ground-mass, when the nicols are crossed, splits up into differently oriented optical groups of units, without any particular shape that I could discover, except that the groups are bounded by more or less straight lines. Each optically uniform quartz group is approximately coincident with each intergrown optically uniform felspar group, though they do not extinguish light simultaneously.

The generally accepted theory of eutectic compounds crystallizing often in a pegmatoid manner, that is to say, by mutual simultaneous intergrowth, is one which has a great deal of evidence in its favour. There is one point, however, that I would notice in connection with the question, namely, the apparent difficulty of always distinguishing the so-called quartz of corrosion structure from a product of mutual intergrowth of quartz and felspar. There seems to me to be a more than superficial relation between the two. I have referred to this point before (Rec., G. S. of I., XXI, pt. 1), and it has again been brought to my mind by the recent paper by M. Al. Lacroix on the scapolite-bearing rocks of Ceylon and Salem translated by Mr. Mallet (Rec., G. S. of I., Vol. XXIV, pt. 3). It seems to me that quartz of corrosion in felspar, and quartz intergrown with felspar, may sometimes resemble one another so nearly that it is difficult to believe that they had an entirely different origin in each case, namely, by subsequent corrosion of the felspar with deposition of secondary quartz in the one case, and by mutual inter-growth and crystallization of the two minerals in the other case.

Among the micropegmatitic ground-mass there are grains of quartz of compound crystalline structure but much cut up by fissures. These fissures are sometimes widely open and show either invasions of some green mineral or of the altered felspar material. Crystals of felspar very much altered like that of the micropegmatite, but with regular outlines, are seen scattered through the ground-mass: and occasionally round them and round the quartz there is a partial coincident extinction of the micropegmatite. The felspar shows no compound twinning indicative of plagioclase; there is one binary twin in the slide.

There is a little green mineral in the rock which is probably altered hornblende, and magnetite is very scarce.

No. (7), $\frac{8}{473}$, 656. Macroscopically a black rock, with compact pitch-stone-like matrix, containing small white and pink patches of quartz and felspar.

Microscopically the slide appears as a quartz-felsite or quartz-rhyolite. The ground-mass is yellowish or brownish-grey in ordinary light with flow-structure extremely prominent. The ground-mass is not of uniform colour or structure. Portions are more or less glassy, and remain dark between crossed nicols; other portions are finely felsitic, and others again finely spherulitic, giving an assemblage of black crosses with crossed nicols. It seems probable that the different nature of these patches indicates that the whole did not solidify at once, but that half-solidified portions of a flow were broken up and then half fused over again.

Quartz is present in clear, single, idiomorphic crystals, occasionally corroded at the edges. Felspar is scarce, but not entirely wanting. Magnetite is relatively abundant, as small crystals, or groups of crystals, and also in streaks and shreds following the direction of the flow-lines.

There are lacunæ and small patches of viridite.

No. (9), $\frac{8}{475}$, 658. In the hand a fine-grained trappoid rock of black colour.

Under the microscope this appears as a clastic rock, an ordinary grit of very fine grain. There is a pale yellowish green mineral giving aggregate polarization colours between crossed nicols, probably decomposed mica: Magnetite in grains is also present.

No. (9*a*), $\frac{8}{476}$, 659. This is also a fine-grained clastic rock, finer than the last.

No. (10), $\frac{8}{477}$, 660. In the hand this is a banded mica-schist containing black mica and quartz.

The microscope slide displays a typical crystalline mica-schist, with dark mica and a fair amount of orthoclase and plagioclase besides the quartz. The dark mica is of olive green tint, though there is a little white mica as an accessory. The packets of biotite arrange themselves in among the quartz grains and are sometimes bent. In ordinary light the ground-mass of quartz is quite transparent and structureless, save for a few small inclusions, probably minute garnets. With crossed nicols it breaks up into an irregular aggregation of different optical units, most of which are irregularly lens-shaped, with the long axes parallel to the foliation. Undulose extinction is frequently observable in the quartz. That the rock has succumbed to pressure at right angles to the foliation I have no doubt, but it seems to me a probable surmise in this case that the rock was formed originally as a mica-schist under enormous pressure.

No. (11), $\frac{9}{478}$, 661. Macroscopically a dark grey quartzite.

Under the microscope it appears as a typical quartzite.

The most noticeable feature in this slide is the abundance of large inclusions in the quartz grains.

No. (12), $\frac{8}{479}$, 662. A dark purple quartzite (?).

Microscopically it contains much felspathic material and might represent a metamorphosed arkose.

No. (13), $\frac{9}{480}$, 663. Macroscopically it is a purplish grey, fine-grained volcanic ash (?).

Under the microscope it contains apparently a fine-grained felsitic ground-mass, with an indefinite parallel-banded structure. But it has some curious features. The whole of the ground-mass does not split up into a mosaic, but there appears to be underneath it all a completely isotropic base in which crystalline particles show up here and there.

There are grains of quartz scattered about in the matrix, but they are all much split and broken. None of them possess those corroded outlines so common among the quartz-grains of quartz-felsites. There are some crystals of felspar with binary twins, also much fractured.

Much opacite occurs in smudgy streaks.

The nature of the ground-mass, and more especially the slight difference of coarseness here and there, together with the angular and fragmentary state of the crystalline contents therein, which at the same time are not corroded, lend colour to the supposition that the rock is a volcanic ash composed chiefly of felsitic material.

Besides the general resemblance between Nos. $\frac{8}{467}$ and $\frac{70}{60}$ already alluded to, there is nothing but a distant family likeness between other boulder specimens and the few slides of Melani and other rocks sent me. The family likeness consists in the prevalence among certain specimens in both sets of rocks of a more or less pegmatoid structure. Identities of type are, however, wanting at present. We can gather therefore nothing more than a faint suspicion that the rocks of the Boulder bed were originally derived from the south, rather than from the north.

Subrecent *and* Recent Deposits *of the valley plains of* Quetta, Pishin and the Dasht-i-Bedaolat; *with appendices on the* Chamans *of* Quetta; *and the* Artesian water supply *of* Quetta *and* Pishin: by R. D. OLDHAM, A.R.S.M., F.G.S., *Superintendent, Geological Survey of India* (with one Plate).

Occupying a position intermediate between the highly disturbed tertiary and pre-tertiary rocks of the surrounding hills and the undisturbed recent deposits of the valley plains of Quetta, Pishin and the Dasht-i-Bedaolat, come the beds which were described as gáj by Mr. Griesbach,[1] and subsequently classed as siwalik by Dr. Blanford.[2]

Siwalik they may be as regards their age, using the term siwalik for all upper tertiary beds ranging in age from miocene up to the latest pliocene, but they must not be confounded with the true, or what may be called marginal, siwaliks of the outer hills. The contrast is especially striking owing to the close proximity of the two types; in the area intervening between the Bolán and Hamai routes to Quetta the hills are formed of siwalik beds, which extend continuously to within a few miles of the Quetta plain, and, throughout this area, they maintain a very constant structure. At the base there is often a small thickness of clean grey or greenish sandstones, with a few strings of pebbles or thin bands of conglomerate, but, with this exception, they show everywhere that increase in average coarseness of texture from base to summit, which is one of the most constant features of the true siwaliks. Near the base of the section the series is essentially an argillaceous one, the prevailing rock being a red or brown earthy clay; above this the beds gradually get more sandy, till sandstone is the prevailing rock and in this pebbles appear and gradually increase in abundance and size, till the uppermost beds are almost entirely coarse conglomerates.

The siwaliks of the valley plains differ radically in structure from these. Where exposed on the northern terminations of the Chehiltan and Mashálak ranges, the bottom beds are composed of angular or sub-angular debris of the same cretaceous and lower tertiary rocks as form the summits of these ranges; they are in fact identical in structure, appearance, and doubtless in origin, with the talus and fan deposits, which are at the present day being formed along the margins of these ranges. These beds are succeeded, without the intervention of any well-defined zone of medium grained deposits, such as sandstone, by fine grained clays and sandy beds. Where they have been disturbed and elevated, these have been cut into a network of low hills, absolutely bare of vegetation, and showing most conspicuously the bright colouration of the material they are composed of. Elsewhere, however, these beds tail off to a horizontal dip and cover a large area in the valley plains, extending continuously across the valley at Baléli, and abutting against the foot of the ridge pierced by the Murghi pass, where the relation of the high dipping cretaceous limestone to the horizontal red clays is evidently one of original contact. This, taken with the nature of the bottom beds in the Chehiltan and Mashálak ranges, makes it clear that these

[1] Mem., Geol. Surv., Ind. XVIII, 18.
[2] Mem., Geol. Surv., Ind. XX, 115.

clays have been deposited since the elevation of the mountains bounding the valley plains of Quetta and Pishin.

The siwaliks of the hills, on the other hand, are as clearly shown to be older than the elevation of these hills, not only by their forming an integral part of them and their highest peaks, but by the parallelism of stratification between the lowest beds of the siwaliks, and of the beds on which they immediately rest in unconformable contact. There is certainly a considerable lithological resemblance between the clay of the valley siwaliks and the clay zone at the base of the siwaliks of the hills, and it might be held that these were originally continuous and had since been separated by the elevation of the hills. On this supposition the junction of the valley siwaliks with the cretaceous limestone near Baléli would be a great faulted boundary, the faulting being concealed by a small thickness of subsequent deposits at and near the surface; such a supposition is just barely possible were there not weighty reasons for rejecting it. The most important of these is the impossibility of accounting for the absence of the great thickness of sandstone and conglomerate, forming the upper portion of the siwaliks of the hills, which must formerly have extended over the area occupied by the valley plains, and whose complete removal is inexplicable if their stratigraphical position were that of conformable superposition on the clays of the valley siwaliks. On the other hand, their thickness, close up to the limits of the valleys, shows that, in their original extension, these conglomerates and sandstones must have spread far beyond the present limits, determined by disturbance and denudation, over the area now occupied by the valley Siwaliks, and, as these latter cannot be older, the only alternative is that they are newer than the siwaliks of the hills.

The conclusion is strengthened by a feature in the structure of the siwaliks of the hills. Instead of forming a single conformable system, they form two unconformable divisions, of which the older,—that which is referred to in the preceding passages,—was formed before the elevation of the hills and the great disturbance of the underlying beds; the other or newer, which is almost entirely composed of conglomerate, dating from a period when the older rocks had not only undergone nearly the whole of the disturbance they have been subjected to, but had been carved into deep valleys, and the present drainage system to a large extent already defined. The newer conglomerates rest with a marked unconformity on the eroded edges of the highly disturbed tertiary and cretaceous beds, as well as of the older group of the siwaliks. They can be seen in the Gandak or Sarakhúla valley, where their presence has been recorded by Dr. Blanford. They form part of the hills, east of Khánai, and an outlier of the same conglomerates forms the cap of a very conspicuous hill which rises above the railway line between Fuller's camp and the Bostán valley.

To the west of Khánai, the northern extension of the Bostán valley is bounded by a ridge whose surface is covered by a shingle of limestone and chert pebbles, evidently derived from the weathering of conglomerate beds. Owing to weathering of the beds and the absence of deep-cut stream gorges, no good exposures of rock *in situ* are seen in the conglomerate zone, but the contour of the hills, no less than the structure of the higher parts, shows that the dip of the beds is north-westerly, and

[1] Mem Geol. Surv, Ind. XX p. 185.

that these conglomerate beds graduate upwards, with a more gradual transition than in the Mashálak range, into the clay beds of the Pishin valley siwaliks. Now it seems natural enough to regard these conglomerate beds as closely related to those which unconformably cap the disturbed beds of the hills, east of Khánai and, as these are youngest beds of the siwaliks of the hills and the former the oldest beds of the siwaliks of the valleys, the relation between the two is evident.

It will be seen, from what follows, that these siwaliks of the valleys graduate upwards into the recent deposits of the valleys and that, in spite of local unconformities, the process of formation has been continuously going on in one part or other of the area under description. We have, consequently, another illustration of the two truths that are constantly being borne in on the geologist who works among the upper tertiary beds of extra peninsular India,—(1) that there is no real distinction or constant horizon of demarcation between the deposits of uppermost tertiary and of recent age, and (2) that in beds deposited subaërially in a region that has been undergoing disturbance and upheaval during the period of their accumulation, the stratigraphical value and signification of an unconformity is very different from what it has when found among beds of marine origin.

The siwaliks of the valleys graduate into the next type of deposit to be considered. In the Pishin valley the gently inclined siwaliks, which form the low range of hills lying between the head-quarters of the district and the broad Pishin plain, have a low westerly dip, which gradually flattens off to horizontal, and pass, with perfect transition, underneath a series of fine grained, distinctly stratified, alternating beds, mostly thin, and varying from fine clay to fine grained sand. Very good sections of these beds are exposed in the vertical sides of the numerous nullahs which ramify through them, and especially in the high cliffs which border the bed of the Lorah, and their distinctly stratified nature proclaims them to have been formed by aqueous action, while the absence of anything that could be called a coarse grained deposit, and the rarity of even slight traces of false bedding, show that they must have been deposited in still water. In these features the beds bear considerable resemblance to a lake deposit, and, so far as their appearance is concerned, they might well be of such an origin. It is, however, very improbable that, with so small a catchment area, a large lake could be formed in the dry climate which appears to have characterized Balúchistán throughout the recent period of geology, nor are there any beach terraces, such as one would expect to find had the Pishin valley ever been occupied by a lake. But, though it is improbable that a permanent accumulation of water occupied any portion of the Pishin valley during the recent period of geology, it is more than probable that, before the outlet was deepened by erosion and so allowed the streams to cut deep channels through the plain, large areas of it were subject to temporary flooding after every heavy fall of rain on the surrounding hills. The water, as it left the hills, would carry with it debris of every degree of coarseness, but as soon as its velocity was checked, all the larger particles would be deposited, and the depression would be filled with water, bearing only fine particles of mud and sand in suspension. These, after a while, would subside, and the water would dry up, by the combined effect of evaporation and percolation, but the next flood would bring down a fresh supply of material to be deposited in a thin layer on the top of what had gone before.

The process here described can be seen at work on many of the valley plains of the Balúchistán hills and, as the lowest-lying parts are most often flooded and consequently receive the largest addition of sediment, one of its most conspicuous effects is a diminution of the surface gradients, till they cease to be perceptible to the eye. Now, in the Pishin plain, there is a very conspicuous difference in the surface gradients of the area occupied by these stratified deposits and that occupied by the unstratified loess which will be described further on.

From the foot of the hills to the east of the plain,—if we except a narrow zone in the immediate neighbourhood of the hills,—there is no perceptible gradient over the whole area occupied by the stratified deposits, but, from their limit, the loess rises very perceptibly to the north and west, to the foot of the talus slopes of gravel. This loess slope marks that portion of the plain which lay too high to be flooded, while the rest is the lower-lying portion subject to more or less frequent inundation, in which the gradient of the surface would be less, owing to that more rapid deposition in the lower levels which has been referred to above. It might, of course, be urged that the present extent of the loess marks the encroachments made by the dry land on to a pre-existing lake before it was finally drained, but, as far as the Pishin plain is concerned, the sections in the tributaries from the north, which join the Pishin-Lorah near Alizai, conclusively disprove this hypothesis. Instead of the loess being found overlying stratified deposits, we find that there is a horizontal transition from one to the other. The exact limit of each is not very definite and, to a certain extent, they are found to intercalate with each other, a distance of a quarter of a mile at places even of a couple of hundred yards, being sufficient for the complete replacement of stratified by unstratified deposits, thus showing that, during a period of time represented by the gradual accumulation of over 30 feet of deposit, the horizontal limit between the area which was liable to flooding, and that which was not, remained much the same.

In the foregoing description I have only mentioned the stratified deposits in the Pishin plain, but it must not be supposed that they are confined to it. It has been a matter of convenience to take Pishin as the typical area, because there good sections have been exposed by the streams, and there, owing to the red colour imparted to them by the river wash from the siwaliks, they are more easily recognized. In the closed drainage areas of the Dasht-i-Bedaolat and Gwende Dasht similar accumulations are being formed, but as they are composed principally of rain wash from the loess, and consequently more uniform in texture, the stratification is more obscure, while the absence of good sections, and more especially the identity of colour, renders it more difficult to separate them from the true loess.[1]

As seen in the Quetta and Pishin plains the loess is usually of a pale grey or yellow colour, fine grained in texture, firm enough to allow it to stand in perpendicular cliff of 50 feet or more in height, porous and readily absorbing water and very slightly permeable owing to the minute size of the pores. When broken down with water the loess forms an impalpable slimy clay which, in drying, retains the shape im-

[1] The term loess is here used, in the sense which it has acquired, to designate a fine grained deposit not stratified, or only obscurely so, of Æolian origin, the sense in fact in which it is used by the Baron Von Richthofen in his work on China, and without reference to any consideration as to whether it is or is not the same in age or origin as the typical loess of the Rhine valley.

pressed on it when moist, and is used for the manufacture of bricks of fair quality. In the composition of the loess there is always a considerable proportion of carbonate of lime, so that it effervesces freely with acid, and this is distributed evenly through the mass in the shape of minute grains, which are doubtless dust derived from the surrounding limestone hills. The other ingredients are equally minute granules of quartz and of argillaceous matter, the last enabling it to be used as a brick earth while the large proportion of lime renders it very easy to overburn the bricks. Small calcareous concretions, or *kunkur* nodules, occur, but they appear to be rarer than in the loess of China, and I have not been able to detect the numerous vertical tubelets which are described by Von Richthofen. In all other respects, both of texture, composition, structure, and in the contour of its surface, it agrees perfectly with the descriptions of that observer.

There can be no doubt that this type of deposit is really of Æolian origin; not only is the occurrence of finely comminuted limestone, most unusual, if not almost impossible, in beds formed by water but the absence of stratification points to the same conclusion. Moreover, if deposited by water, it must either have been formed at the bottom of a deep lake or in an alluvial plain. The shape of the surface would not be inconsistent with the former mode of origin, but there are no traces of those shore line terraces which could not but have been found had such a lake existed. Were the loess, on the other hand, a subaërial alluvial deposit, we would find a plain sloping gently in the direction of the stream, but nearly horizontal in a direction transverse to that, or even higher in the centre than at the sides; such, however, is not the shape of the section across the Quetta or Dasht-i-Bedaolat plain, where the lowest point is always in the centre, and the ground slopes upwards on either side towards the hills. The most conclusive evidence, however, is to be found in the widespread distribution, in height, of similar deposit, and its occurrence, in small patches, on the tops of hills and other places where an alluvial origin is quite out of the question.

In none of these beds have I found any fossils; the siwaliks and stratified beds of Pishin have not been very closely searched, but I have spent some time trying to find remains of shells in the loess. So far, all that has been found are some fresh-water shells, of the same species as are now living, in mud dug from some of the swamps in the valley. I was also shown a specimen of black clayey matter containing fragments of shells in a whitened and extremely friable condition said to have come from a depth of 60 feet in the artesian[1] boring put down in the Residency compound. The shells had been too much broken up by the boring tool to be determined with certainty, but there is no reason for doubting that they were fresh-water shells of existing species. The matrix was undubitably a swamp deposit, and apparently quite local in its extent, for it does not appear to have been met with in any of the other borings put down close by.

Of true fine grained alluvial deposits, formed by overflow of streams, as opposed to those formed in temporary stagnant accumulation of flood waters, there is little to be seen in the area under consideration. The streams all flow in narrow channels, cut below the general surface of the plain, and in the bottom of these

[1] The specimen was not seen by me till after the boring had been completed; no proper record of this well was kept, and the determination of the depth from which the specimen came depends merely on the memory of the driller in charge.

there are occasional stretches of alluvial land, but beyond this nothing. Coarse-grained gravel deposits are however abundant and conspicuous in the broad talus fans, which spread out from the mouth of every valley, as it leaves the hills. They are the often-described "fans" or "*Cones de déjection*," formed of water-borne debris of various degrees of coarseness, the actual slope of the surface depending on a variety of circumstances, the principal of which are the volume of water which pours down in flood time and the average size of the debris carried; it varies from about 300 feet to 600 feet per mile, slopes higher than this being found, but, I believe, in every case these are due to disturbance subsequent to formation. In the actual channels usually followed by the streams the gravel is tolerably clean and easily permeable, but over the greater area of the fan, where its surface is not now washed by the streams, the stones are mixed with a varying proportion of wind-borne dust, which may even completely obscure the underlying gravel and form a surface of pure loess. Sometimes, as on the north-east of the Quetta plain, the smooth glacis slope of the fan is separated from the hills by a region where the slope is steeper and where the gravels have been cut into an undulating surface intersected by valleys. The distinction of surface is very marked, and is difficult to account for unless we suppose that part of the fan has undergone disturbance, by which its surface has been thrown into a steeper slope than that at which the gravel is naturally deposited, and, in consequence, the water flowing off has been able to cut it into hill and vale.

Besides the gravels of the glacis slope or "Dháman," the streams push long tongues of gravel over the loess area and, as the streams from time to time have altered their courses over the fans, the direction of these tongues has varied accordingly and they have been successively covered up by the gradual accumulation of loess. One of these underground tongues of gravel formed by the Hanna stream can be traced near Sherdil, two miles from the edge of the gravel fan, where an area of some acres of ground is riddled with karéz shafts, some of which, lying along a well-defined line, have struck gravel, while others have found nothing but loess.

These stream deposits have been only cursorily described as they present no important features of interest or novelty so far as their structure or mode of occurrence is concerned. Economically, however, they are most important, for it is to the tongues of gravel that we must look for a supply of artesian water, while in the fans themselves is a source of water-supply which, when tapped by the karez, is a most important element in the agricultural economy of these valleys and of all the drier parts of Central Asia.

A digression regarding the theory of the karez.—As the theory of the karez is a matter on which much misconception is prevalent, it will be well to treat of it briefly. The ordinary explanation is that an "underground spring" having been discovered, a series of shafts connected by tunnels is made, by which the water is brought out to the surface. This idea of an underground spring is extremely prevalent and owes its origin to the description of the natives who have frequently told me that the water entered their karezes from springs. I have scrambled through the underground passages of some of these karezes to investigate the matter and have found, as might be expected, that the description is a natural but misleading one. In a few cases the karez does appear to derive its supply from what may without great

impropriety be called an underground spring. Such are the karezes between Kuchlák and Baléli which are driven through impervious siwalik clays up to the foot of a limestone ridge; it is not from the siwalik clays that they could derive any supply of water, so it is probable that there are here springs issuing from the solid rock. A still more striking instance is a short karez at Karáni driven, not into either of the fans which lie to the north and south of the village but towards the hill where there is no stream valley of any size, yet this is not only the shortest but one of the most abundant karezes I have seen: here, too, it seems probable that the water is supplied by a spring issuing from the solid rock. Such cases are, however, very exceptional, and, as a rule, the explanation, both of the real facts and of the origin of the misconception regarding the action of the karezes, is very different.

As the karezes are never lined in any way, it is impossible to drive them through incoherent material charged with water; it would moreover be unnecessary to do so as, if an incoherent bed of sand or gravel charged with water were once struck, the supply would amply satisfy the desires of the karez-diggers. The karezes, then, after they enter ground charged with water, can only be driven through stuff which is rendered coherent by a greater or less admixture of cementing material. But this cementing material not only renders the ground firm enough to form the sides and roof of the tunnel, but lessens the permeability of the ground and, what we are more concerned with, makes it irregularly permeable. When the karez is driven through such a deposit, the water will first of all drain away at those spots, where it is most permeable, very probably washing out the fine-grained matrix and forming a small channel penetrating to a greater or less distance from the sides of the tunnel. Into this channel water will percolate and, instead of oozing from the sides, enter the karez principally at certain defined spots, giving rise to what are called springs. The origin of the commonly held idea is thus natural and easily explained, but to call these "underground springs" is a misnomer and as misleading as it would be to apply the same name to an ordinary surface well.

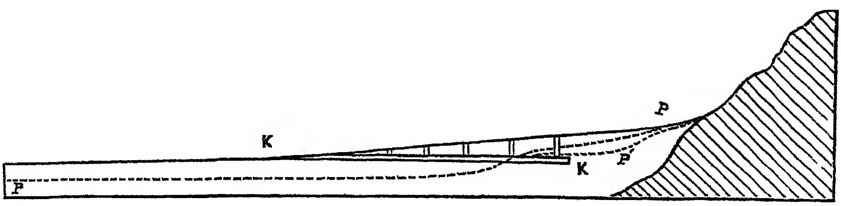


Fig. 1.—Diagram to illustrate the theory of the karez.

Having stated what is not, it is now necessary to describe what is, the correct explanation of a karez. In fig. 1 a diagrammatic section of one of the gravel slopes is represented; the dotted line *p.p.* represents the limit of permanent saturation, that is the limit below which the gravels are always charged with water even in the driest season. Such a limit exists everywhere, but the form of its contour depends on a variety of conditions, such as the rainfall, discharge of streams at the head of the fan, permeability of the gravels, etc., which need not here be considered in detail. Now, if the karez *k.k.* is driven into this slope, that portion of it which lies below the line *p.p.* will drain the sub-soil of its water and discharge this at the outlet.

It will be seen from this that in its nature and mode of action the karez is only a sub-soil drain; in both cases the object is to bring water which lies underground to the surface, the only difference being that in the one case it is desired to obtain the use, and in the other to get rid, of the water.

From the nature of the case these karezes are affected by the rainfall in a marked manner,—a single dry season, and still more a succession of years of deficient rainfall, causes a diminution in the discharge of the karez. Last year (1890) the falling off of water-supply was very widespread and, so far as the diminished discharge was only due to the dryness of the season, was not altogether an unmixed evil, for it led to an energetic cleaning out and in some cases lengthening of the karez which will improve its ultimate capacity. In a new karez, however, the failure may be due to another cause, which is more serious, as it permanently affects the supply of water, and may make this fall so low as to lead to the abandonment of the karez.

When the karez *k.k.* in fig. 1 is first made, water will flow freely into it from the surrounding gravels in all that portion which lies within the original limit of permanent saturation. But, after it is completed, a new outlet is provided for the sub-soil water, the limit of permanent saturation will adapt itself to the new conditions, and ultimately settle down with a profile which may be represented by the line *p. p'. p.* The subsequent history of the karez will now depend on the relative importance of the causes which led to the sub-soil water originally maintaining its level along *p.p.p.* If the gravels were tolerably permeable and a considerable supply of water was constantly percolating through them, the karez will settle down to a fair or abundant discharge. If, on the other hand, the amount of water percolating was very small and the level of permanent saturation kept up by the impermeability of the gravels, the ultimate conditions of the karez will be one of very small discharge.

I do not know to what extent this cause of failing supply of water has acted, or is acting, but there can be no doubt that, except in the case of old-established karezes, it must to a greater or less extent be at work. I made many attempts to collect information which would bear on this point, but was baffled by ignorance, reluctance to impart the information, or an inability, real or pretended, to understand the points regarding which information was desired. I was unable even to arrive at a trustworthy conclusion as to whether the reputed diminution of supply was as common, or as extensive, as was complained of, and this, when we consider how many reasons the proprietors have for complaining of a failure of water-supply and the absence of any inducement to acknowledge an increased discharge, is not to be wondered at.

As might be expected in a country where water is so valuable and apparently so mysteriously capricious in its occurrence, a class of men has arisen which pretends to a special knowledge of the underground distribution of water and to them the planning of new karezes appears to be principally entrusted. I have not met any of these men, but so far as I can gather they seem in some cases to possess a certain amount of knowledge, partly inherited, partly the result of observation, of the subject they profess. This is doubtless mixed up with a good deal of superstition, but as their directions are received with the same implicit belief as their rulers grant to the dictum of any self-styled "expert," the shaft, sunk on the spot indicated, is carried down till it reaches water, whereby the reality of his knowledge is proved.

Meanwhile he takes care to conceal the knowledge—if he possesses it—that there was no special virtue in the spot selected, and that there are many other places where a shaft would be equally certain to strike water, if given the same chance. Should water not be found, his employer is probably informed—for there is a close resemblance between the various species of the genus expert—that he did not go deep enough, or that though water was not found just there "the indications are very favourable," he is recommended to try some other place near by, and, if his patience or capital be exhausted before water is obtained, the expert, following the example of his kind, takes himself off to another country where his ignorance has not been exposed, there to find that ready credence which mankind is prone to yield to a plausible assertion of knowledge and, with better luck, repair his damaged reputation.

The amount of labour spent on some of these karezes, and the depth of their numerous shafts, is astounding; they are frequently miles in length and the shafts near their heads are said to be in some cases 150 feet deep. This is doubtless an extreme case, but, when examining the Quetta plain, I found that in many cases the shafts at the head of those which drain from the hills, east of the valley, could not be plumbed with the 70-feet line I carried with me. These must have taken many years and cost large sums to excavate, but it is probable that the whole was not made at once, and that they were gradually lengthened at their upper ends, where they are deepest out of the profits derived from the water which the original shorter channel yielded.

The Chamans or Artesian Springs of Quetta.

Among the most remarkable features of the Quetta plain are the numerous *chamans* or *chinnas*. The first of these words meaning a grassy spot, the second a spring, their nature is at once indicated. Riding across the naked plain, bare of vegetation where it is lying fallow or after the crops have been reaped, one suddenly comes on a green spot and water. Sometimes these are mere marshy spots, from which a small driblet of water may trickle away, but more commonly there is a pool, and not infrequently a strong spring of clear water issues from the soil.

There is a very conspicuous instance of this to be seen on the western bank of the Lorah just where it is crossed by the military road from Quetta to the Gháziáband pass. Here a strong spring of clear water with a discharge of several thousand gallons per hour issues from the scarped face of loess, as if from a rock. So too, about two miles from Quetta on the road to Sariáb, in one of these springs a short way west of the road, the water can be seen issuing with some force from the bottom of the pool. To the west of Quetta there is a series of these springs, draining one into the other and finally forming a considerable body of water, which has cut for itself a valley of some 20 feet depth in the loess. The great bulk of this water issues from the lowest of the springs, a pool of 20 feet diameter with a level bottom about 2 feet from the surface: this bottom is not, however, solid, but a very mobile quicksand kept in constant motion and surging to and fro by the action of a stream of water which is constantly forcing its way upwards from below. In 1888

a plummet was sunk into this, by Mr. P. Duncan, Executive Engineer, North-Western Railway, to a depth of over 100 feet before it was stopped, most probably by the friction of the sand on the sounding-line. From this it was evident that the water came from a considerable depth through a well-defined channel, and the nature of the spring stood confessed as a natural artesian well.

These springs vary considerably in size; from some there is a copious discharge of water, others again barely moisten a small patch of a few feet across, while yet another category is formed by those which, though they now have but a small discharge, show, by the sand heaped up over their orifices, that the water once issued with sufficient force to carry it up from below, the flow having since been checked by the falling in of the sides of the channel through which it flowed, by the heaping up of sand on the surface, or by both causes combined.

The most extensive of those belonging to the last category that I am acquainted with lies west of Quetta and covers about a couple of acres of marshy ground. Yet this is not a marsh of the type which is usually seen in the low-lying parts of valleys, where the level of permanent saturation rises to the surface, but it is distinctly raised above the level of the surrounding country, and on all sides water drains away in small driblets into the lower level of the loess plain. Between this and Quetta there is a very perfect little chaman, a low conical mound of about 20 yards in diameter, and rising some 4 or 5 feet above the level of the plain. at its apex, is a small pool of clear water and the whole recalls, on a very small scale, the description of the Hawaian volcanoes. Nor is the resemblance merely one of form, for there can be no doubt that just as these volcanoes have been built up of material poured out from the crater, so this has been built up of material brought from below by the water, which for some reason no longer issues with the force it used to.

Whatever may be the underground structure of the Quetta plain, the existence of water under pressure has been amply proved by the numerous successful artesian wells that have been sunk, but it still remains to be seen how the defined channels through the overlying deposits could have been formed before the "chamans" have been accounted for. In the case of those from which there is a copious discharge of water, it is conceivable that the channel might be kept open during the gradual accumulation of the loess, as any dust settling over the spring could be washed away as fast as it was deposited. In those far more numerous cases where there is little or no discharge such an explanation is not admissible, as there is no flow sufficient to keep the channel open against the continuous raising of the surface of the plain, and, in course of time, all these are certainly doomed to extinction; it might be urged that this is so, that these chamans which have so small a discharge were once copious springs, whose flow has been gradually reduced as the level of the surface was raised by the deposit of loess, and that the chamans, once much more abundant than they now are, have steadily diminished in number, as one after the other became obliterated by the same cause. The first objection to this is that, taking into consideration the great proportion of these springs whose condition is such that they would be obliterated by a very small increment to the thickness of the loess, small, that is to say, in proportion to the total thickness that has been deposited, and supposing that their destruction went on at the same rate throughout, the original number of the springs would have to be inconceivably great.

The most serious objection, however, is that the hypothesis is not a real explanation of the difficulty; as long as the water-bearing stratum formed the surface of the ground artesian conditions could not arise, and it is only after it had become covered up by a considerable thickness of fresh deposits that water could accumulate under pressure. Let us assume that only half the present cover was sufficient to produce artesian conditions, it is almost as difficult to understand how well defined vertical channels could have been made through 50 feet, of so necessarily homogeneous a deposit as the loess, as through 100 feet, and so we are landed once more in the same perplexity as before. Were it possible to suppose that these chamans marked the sites of old rock springs, whose flow had preserved an open channel through the gradually accumulating deposit in the valley, a natural explanation would be available, but the numerous borings put down at Quetta leave no doubt that such is not the case, that water under pressure exists below an extensive area, but that only locally and along defined channels does it obtain access to the surface.

The problem then is this, we have a permeable bed or beds containing water under sufficient pressure to make it flow at the surface as soon as it is afforded an outlet; we have overlying this a thickness of 100 feet or more of deposit homogeneous and practically impervious, except for certain defined channels reaching down to the water-bearing bed which can only have been formed after a considerable portion, if not to all intents and purposes the whole, of the deposit they penetrate had been accumulated. To account for these channels by natural causes seems impossible and the only resource lies in the hypothesis that they are the work of man, that the chamans in fact are in their origin artificial not natural artesian wells.

The idea, startling as it is, is not so absurd as it seems at first sight, the experience of the last two years has shown that the simplest and rudest appliances would suffice to put down a bore-hole through the fine-grained loess, and there are not wanting indications that the Quetta valley was once occupied by a race more civilised and energetic than the present indolent and apathetic inhabitants.

Scattered over the Quetta and adjoining plains there are a number of artificial mounds, varying in size, of which the largest and most conspicuous is the Miri, or citadel of Quetta. Owing to the earth from these being valued as a manure, some of them have been deeply dug into and they can be seen to be entirely of artificial origin and gradual growth; they are composed of innumerable layers of ashes and rubbish, mixed with earth, and have grown in size partly by the addition of material with deliberate intention of raising their height, but principally by the unintentional, steady raising of the level which goes on in every thickly populated locality through the constant bringing in of fresh materials for repairs to existing and the erection of new buildings. Originally they were probably the refuge forts for a race to whom the use of metals was unknown, but in their later stages they were occupied by a race which was not only possessed of the art of pottery, but made and used well-formed and well-baked bricks of a large size. Besides this, during the excavations made in the Quetta mound, Greek coins and a statue of Hercules were discovered, which show that the people who owned this fort 2,000 years ago had intercourse with the Western world. There is no great difficulty in supposing that this people possessed the art of boring for water, the difficulty is to understand how the art became lost, but an explanation may be found in the long

period of anarchy and internecine warfare which the country is known to have gone through.

The explanation mooted here has at least the advantage of accounting for the facts; it accounts for the existence of well-defined channels through the otherwise homogeneously impervious loess, and it also accounts for the differences in discharge from the different chamans. I have said that to bore down through the loess to the gravel beds is a task which can be accomplished with the simplest of appliances, but once the gravel is struck, to carry the borehole further would require appliances which we cannot suppose were at the disposal of these ancient inhabitants of the Quetta plain. Consequently the discharge from a borehole would depend on the nature of the first gravel bed struck. If the gravel were so mixed up with loess as to be quite or almost impervious, there would be no discharge, the well would soon fall in and become obliterated; if, on the other hand, the stuff struck immediately below the loess were freely permeable, the water would issue in large volumes carrying with it quantities of sand, as actually happened in the case of some of these chamans. Between each of these extremes every gradation might occur, as the greater or less degree of permeability of the water-bearing beds where struck, and the hydrostatic pressure of the water contained in it, admitted of larger or smaller discharge into and from the borehole.

Examples of both extremes of discharge can be found among the artesian borings put down during the last two years in Quetta. Two of these, put down by hand-power without any casing and carried only as far as the water-bearing bed, were sunk in the Residency Surgeon's compound; the first of these yielded a moderate flow of water, quite sufficient to keep the borehole clear, the second struck the gravel where it was less pervious and failed to give any discharge. The history of the pioneer well, that at the Railway station, is different. This was put down by steam-power with all the appliances which modern ingenuity has perfected. When the gravels were struck there was only a moderate discharge, but the well was carried on till, at a depth of 140 feet, a freely permeable bed was struck, from which the water commenced to flow, bringing with it large quantities of sand, till ultimately the well attained a discharge of 20,000 gallons per hour. Had this freely permeable band immediately underlaid the loess, the water, when first struck, would have issued with force, carrying up with it sand and loess washed from the sides of its channel, and doubtless ultimately have settled down to a copious spring of water similar to those referred to above.

Such is what appears to me the only feasible explanation of the chamans of the Quetta plain. That there are difficulties in the way I do not deny. It is hard to believe that the present race of inhabitants ever possessed the art of sinking artesian wells and we must look to their predecessors, a people who must have differed in character and may have been the same as those who built the "ghorbastas" of Sarawán, those extensive and carefully planned masonry works which have attracted the attention of more than one traveller, which also, like the artesian wells of Quetta, were intended to increase the agricultural capabilities of the land.

The restriction of these artesian springs to the Quetta plain, with the possible exception of one near Bostán, and their absence over the Pishin plain and Dasht-i-Bedaolat agrees very closely with the probable limitation of the area in which artesian water exists a a depth at which it would be accessible. At Bostán easily

accessible artesian water is known to exist, but the area over which it is likely to be found is very small and the pressure in the solitary boring put down was barely sufficient to make it flow at the surface. Under these circumstances it may be that one or two failures discouraged further attempts, or it may be that the pressure and flow of water was so small that boreholes, which once existed, have since fallen in. It must also be remembered that the sinking of these bore-holes with the primitive appliances available would be a work of time; the art may have originated or been most energetically carried on in the Quetta plain and, before the full capabilities of the other valley plains were developed, an irruption of barbarians destroyed at once the civilisation and the skill which had given birth to these undertakings.

This is, of course, a matter of conjecture impossible to substantiate, what is certain is that the chamans of the Quetta plain are essentially artesian wells, that the water rises by well-defined channels through a homogeneous and impervious cover from an underlying pervious bed, in which it exists under pressure, and that the bulk, if not the whole, of this cover must have been deposited before the passages were opened between the water below and the air above. These passages may have been opened by natural causes, but the most probable explanation, taking all things into consideration, is that they were made, with the deliberate intention, by a race the very memory of whom has now been forgotten.

On the mode of occurrence and probable distribution of artesian water in the valley plains of Quetta, Pishin, and the Dasht-i-Bedaolat.

In an attempt to decide whether artesian water exists under any particular spot, the first thing is to arrive at a definite conclusion as to the structure of the ground, and the cause of the pressure which makes the water rise to the surface when tapped by a borehole. The ordinary text-book explanation of an artesian well being inadequate and altogether inapplicable to the Quetta plain, it will be necessary, in the first place, to consider this question and then proceed to the application of the conclusion arrived at.

In the case of the Quetta wells the ordinary popular explanation is that the pressure comes from the surrounding hills, but a very slight consideration will show that there can be no continuity between the highly-disturbed ancient and indurated rocks of the hills, and the soft, nearly horizontal deposits of the plain which are still in process of formation, and consequently it is impossible in a general way that the pressure of the subterraneous water in the latter can be due to the greater vertical elevation of the former. There is, however, a particular circumstance of structure in which the pressure of the artesian water might come from the surrounding hills. If we suppose a subterraneous spring to issue in a patch of coarse-grained permeable deposits, *t. t.* in plate 1, fig. 1, such as one of the minor talus fans, and this patch of permeable deposits to be subsequently covered up and sealed by the deposit of fine-grained impermeable beds, *L. L.* of the same figure, there would be a small area in which a boring would be able to obtain artesian water, whose pressure would really be directly due to the water which soaked into the surrounding hills at a higher level. Such conditions are probably very exceptional, but the possibility of their occurrence must be borne in mind.

A more rational explanation of the pressure is that illustrated by the diagram section, fig. 2. This figure is analogous to the ordinary text-book explanation of an artesian well, on what may be called the basin theory, and in the case of the Quetta plain, such conditions do indubitably exist to a large extent. The rock basins in which the recent deposits of the Quetta and neighbouring plains have been formed are due to "earth warping," as it has been called, that is, to an elevation of the outlet of the drainage at a rate greater than the stream was able to cut downwards' whence the velocity of the current was checked and deposits accumulated over a large part of the basin so formed; the first deposits being coarse-grained permeable stream gravels and sands which were afterwards covered up by fine-grained deposits. The exact proportion of the valley so underlaid by a floor of permeable grained deposits would depend on the rate of elevation of the outlet, and the original contour of the ground, none of which are now determinable with accuracy; broadly speaking, the floor of coarse-grained stream deposits will be continuous over the original main and tributary valleys, while the fine-grained deposits will be to some indeterminable extent in direct contact with the underlying rock on what were originally the spurs.

But though there is doubtless such a continuous floor of gravels, and though it is to this only that we can look for artesian water in the central parts of the valley plains, it by no means follows that this is the source of the artesian water that has so far been obtained, and a study of the records of the wells put down, as yet leads to a different conclusion.

The first artesian well in Quetta was put down in the summer of 1889. The next well in order of time to be sunk was that in the compound of the Political Agent, Quetta and Pishin, which also struck water and was followed by a number of others, particulars of which, so far as they are available, are given in the appendix. If all these wells have been sunk to a layer of porous deposit, which lies directly on the rocky floor of the valley and is overlaid by the finer deposits, we would hardly expect to find great differences in the depth at which they struck water, as the upper surface of the coarse deposits would be smoothed off to a fairly uniform slope by the action of the streams. But if we remember the tongues of stream deposits which are thrust forward from the main body of the fans over the surface of the fine grained loess, we can arrive at a simple and intelligible explanation. On this hypothesis the deep wells would penetrate the older tongues which, when the stream broke away from its course, became covered up by fine-grained deposits, till, at a later period, the stream again took a course approximating to its older one and formed the tongue from which the shallower wells derive their water. The conditions here indicated are graphically explained in the diagram section. fig. 3, which indicates a condition as favourable for the production of artesian wells as that in fig. 2, and is more in accordance with the facts at present known.

The only alternative hypothesis is the improbable, though not impossible, one that these wells have all been sunk on to lines of talus debris, and derive their water from a subterraneous spring, as is represented in fig. 1. Besides its inherent improbability, the nature of the gravel and sand brought up from the borings, so far as I saw it, does not favour this hypothesis. The pebbles were all more or less rounded and, especially the fine gravels, showed such signs of the action of running water that it is difficult to believe that they were not deposited by a running stream;

a supposition strengthened by the alternation of coarse and fine-grained material exhibited by the boring put down in the compound of the office of the Superintending Engineer, Sind-Pishin Railway. The question would soon be settled by a single boring carried down through the shallow water belt to the solid rock, or to the fine-grained impervious beds which should be found, if the explanation I regard as the more probable is the true one.

It would be too much to expect private enterprise to go to this expense, but seeing that nearly all the wells sunk, or being sunk, are Government wells, it does not seem too much to ask that one should so be driven on, even after water has been obtained, and if two or three others were sunk in properly selected spots in the neighbourhood of Quetta and driven as deep as possible, unless previously stopped by rock, a satisfactory conclusion regarding the true conditions of these wells will be arrived at. Nor would this be of merely theoretical interest—that bug-bear of the so-called "practical man"—but the knowledge so obtained, by enabling us to predict with some approach to certainty the probable result of boring for water at any spot, would result in a more economical expenditure and a prevention of the waste of money which will be inevitable if the principle followed is that of putting down a boring wherever it is thought that water would be desirable, irrespective of any considerations of the possibility of success.

In the meanwhile, it is impossible to determine with certainty the exact conditions under which the artesian water of the Quetta plain occurs, but the evidence available is so far in favour of the hypothesis I have suggested, illustrated by fig. 3, that I shall adopt this as the best working hypothesis available, and in the portion of this report which is devoted to a determination of the areas over which artesian water probably exists, shall base my conclusions principally upon it.

The Gwende Dasht and Dasht-i-Bedaolat have been least fully examined of any of these plains. They are both areas of closed drainage, both are remarkably level and characterized by an absence of large fans on their margins, the fine-grained deposits of the plains often extending right up to the foot of the hills. This absence of fans is due to the absence of any large streams draining on to the plains, and such small streams as do issue from the hills cannot extend far over the plain owing to the flatness of the surface. The recent deposits of both these plains seem, as far as could be judged when merely travelling along the road, to consist entirely of wind-blown loess, which has in many places a distinctly reddish tinge when wet. The lowest parts of these plains are, however, regularly flooded after heavy rain, and it is probable that there finely stratified deposits are formed, though, from the nature of the case, no sections can be observed.

The conditions here are altogether adverse to the occurrence of artesian water. The thickness of the loess is probably very great, and the coarse-grained beds which underlie it, have been cut off by its extension from any but a very small accession of surface-water at the margin of the plain. The very gentle surface gradients prevent the formation of long tongues of gravel extending into the plain, and the conditions of deposit to which the low surface gradients are due, have probably continued through the accumulation of some hundreds of feet of loess. The only part where there is any promise of success is in the extreme north-west corner of the Dasht-i-Bedaolat, where a larger stream than usual enters the valley, and there is a well-marked, though not very large, fan; a boring sunk a couple of miles

from the edge of this might find water, but I cannot regard the prospect as promising.

The watershed separating the Dasht-i-Bedaolat from the Quetta plain is formed by great fan-shaped accumulation of loess and gravel. This does not appear to me to be altogether a slope of deposit, but largely due to a warping of the surface in consequence of differential movements of elevation. However this may be, on crossing the watershed we enter a valley plain, which differs most markedly from the Dasht in the abundance of well-defined and extensive gravel fans, and in the distinctly noticeable slope of the surface towards the centre of the plain. The valleys of the streams within the hills are in many cases larger than those which drain on to the Dasht, and this, combined with the surface slope, enables them to send long tongues of gravel out into the plain. To this circumstance appears to be due the prevalence of artesian conditions in the centre portion of the Quetta plain, as evidenced not only by the successful artesian wells which have been sunk, but also by the numerous "chamans," or artesian springs, which are scattered over an area of seven miles from north to south, and three miles from east to west, in the central part of the valley. Over all this area, which includes the whole of the civil station and the western half of the cantonment of Quetta, water may be bored for with a probability of success; failure is, of course, possible in the sense that at any one particular spot the boring may miss the gravel tongues, and fail to find water at a depth which would make it worth while boring for.

To the north, along a sinuous line with a general east and west trend, about a mile south of Baléli, the red siwalik clays crop out at the surface and form a plain, rising slightly above the level of the loess, from which some low hills rise to heights varying up to about 40 feet. North of Baléli these siwaliks range right across the valley and abut against the hills on the east. Owing to the structure of these beds, artesian water probably exists under all this area, but at so great a depth as to make its extraction unprofitable.

About Kuchlák a strip of loess separates the siwaliks from the limestone hills to the east, and at its southern end is the fan at the mouth of the Murghi pass. Near this artesian water might be obtained, but it is doubtful, as the stream and fan both appear to be too small to produce the necessary conditions. A borehole was put down at Kuchlák village in 1890, but without success; failure, however, was only what should have been looked for here, as it is too far north to be supplied by the Murghi pass stream, and there is no other stream capable of producing the necessary conditions.

To the north of Kuchlák the siwaliks again extend across the valley and probably abut against the hills, though, at the surface, they are covered by talus. East of Bostán there is a large fan, whose southern margin runs on to the siwaliks, doubtless overlying them, and in this direction the chance of finding water is very problematical. On the northern slopes of the fan the conditions are different; here it tails off into loess, in which the presence of artesian water has been proved by the successful well sunk near the railway station. The area over which artesian water may be expected to occur, lies northwards from the village of Kasim Khán and east of the line of railway, but to the west of a line drawn from the village of Kasim Khán to the railway station, success is problematical, while north of the line of railway it appears to be impossible.

The Pishin plain is more extensive than any of the others and has not as yet been fully explored. All the eastern part of it is composed of finely stratified deposits, and over this area if artesian water exists at all, it is probably only at such a depth that it would not pay to bore for it. Along the northern and eastern margins of the plain, unstratified loess like that of the Quetta valley comes in, and there are several large fans of gravel. The resemblance in these respects suggests the possibility of a similar occurrence of artesian conditions, and I would suggest that experimental borings should be put down at about three miles from the edge of the Gulistán fan, in a south-easterly direction from the village, and at a similar distance south of the edge of the gravel fan at Alizai on the north of the plain.

It will be seen from the foregoing that the area over which water may be bored or with a prospect of success is much smaller than the expectations of those whose hopes have been raised by the successes at Quetta would lead them to suppose. It must of course be borne in mind that the conclusions have been based entirely on an hypothesis which is not the only possible, though the most probable one. But this is of the less importance as we are concerned principally with those areas over which water can be obtained at a moderate depth, deep borings being inadmissible from their expense where the water is required for agricultural purposes and only justifiable where special circumstances necessitate the procuring of a supply of water at whatever price it may cost. The area over which water can be obtained by borings of moderate depth would not be increased, but rather diminished from that described in this report, were any other hypothesis adopted than that on which I have based my conclusions.

SECTIONS OF BORE HOLES AT QUETTA AND BOSTÁN.

1. Well at Railway station—
   120 feet loess.
   20 feet gravel, underlaid by quicksand.
   Discharge 20,000 gallons per hour; hydrostatic head 50 feet.
2. Well in Political Agent's compound—
   115 feet loess.
   8½ feet shingle with a little artesian water.
   2 feet loess.
   Gravel, an abundant discharge of water.
3. Well in Loco. Superintendent's compound—
   92½ feet loess.
   3½ feet gravel with artesian water.
4. Well in Executive Engineer's (Railway) compound—
   90¾ feet loess.
   10 feet gravel, from which water just flowed at surface.
   10 feet loess.
   20 feet coarse sand and gravel, with an abundant discharge of water.
5. Well at Gymkhana—
   77 feet loess.
   10 feet "hard sandy stuff".
   8 feet "indurated sandy lumps".
   35 feet "clay with nodules".
   3 feet quick sand.
   12 feet hard clay.
   Quicksand with water.

GEOLOGICAL SURVEY OF INDIA

R D Oldham Quetta artesian wells

Records, V

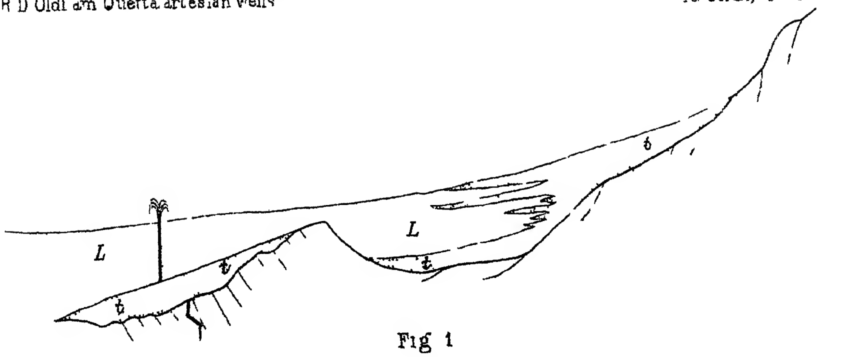


Fig 1

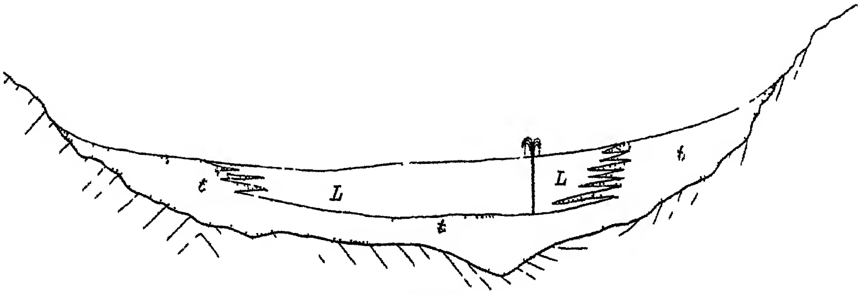


Fig 2.

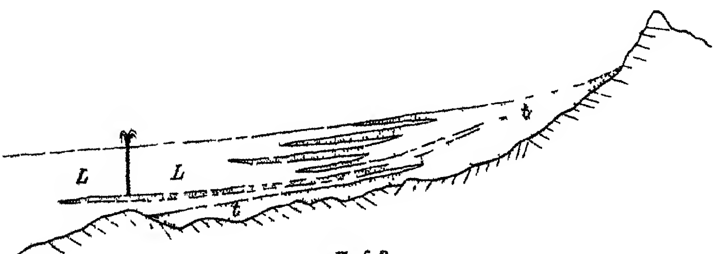


Fig 3

To illustrate possible conditions of occurrence of artesian water

L L fine-grained loess   t t permeable gravels

6. Artesian well at Bostán, as determined from specimens preserved—
   10—20 feet pale yellow unctuous clay containing fine grains of silica and effernescing freely with acids. LOESS.
   20—30 feet the same, but not so fine grained.
   30—40 feet finer than 10—20 feet.
   40—60 feet very like 20—30 feet.
   60—80 feet the same with some pieces of calcareous rock, (kunkur).
   80—90 feet same as 10—60 feet.
   100 feet irregular small pebbles of pale grey limestone.
   180 feet still in gravel, discharge of water 2,500 gallons per hour.
   230 feet or thereabouts, entered as siwalik clays.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 10.—ENDING 31ST JANUARY 1892.

Director's Office, Calcutta, 31st January 1892.

The staff of the Survey is distributed as follows :—

Lower Burma.—THEO. W. HUGHES, A.R.S.M., Superintendent.
P. N. BOSE, B.SC., 2nd grade Deputy Superintendent.
Upper Burma.—C. L. GRIESBACH, C.I.E., Superintendent.
FRITZ NOETLING, PH.D., Palæontologist.
P. N. DATTA, B.SC., Assistant Superintendent.
Punjab.—T. D. LATOUCHE, B.A., 2nd Grade Deputy Superintendent.
C. S, MIDDLEMISS, B.A., 2nd Grade Deputy Superintendent.
W. B. DALLAS EDWARDS, A.R.C.S., Assistant Superintendent.
Sub-Assistant Hira Lal.
Sub-Assistant Kishen Sing.
Madras.—T. H. HOLLAND, A.R.C.S., Assistant Superintendent.
Head Quarters, Calcutta —The Director; and R. D. OLDHAM, A.R.S.M., Superintendent.

Mr. Hughes and his party continue at the tin exploration in Tenasserim: Mr. Griesbach accompanied the north-east Burma Column, and afterwards joined the Irrawadi Column in quest of reported ruby occurrences. Dr. Noetling is attached to the Northern Column in the Amber and Jade country. Mr. Datta is engaged in surveying the country south of Yenangyoung. Mr. LaTouche, with Sub-Assistant Kishen Sing, has taken up the survey of the south-east Takht-i-Suleiman

frontier of the Punjab coal and oil series. Mr. Middlemiss and his party continue the survey in Hazara. Mr. Holland has visited the Chingleput, Malabar, Nellore, and North Arcot districts in connection with his collecting and noting on the iron ore tracts in Madras.

The Director attended the fuel conference at Quetta early in December, and fixed on sites for proposed experimental borings for coal and oil at Sukkur on the Indus. Mr. Oldham continues at the preparation of the new edition of the Manual of the Geology of India.

List of Reports and Papers sent in to Office for publication or record during November, December 1891, and January 1892.

Author.	Subject.	Disposal.
R. B. FOOTE . . .	Geology of the Bellary District.	Will appear as Part I, Vol xxv Memoirs of the Geological Survey of India.
J. W. GREGORY (British Museum).	The Jurassic *Echinoidea* of Kuch.	Will appear as Part I, Vol II, Ser. IX, of the Palæontologia Indica.
P. N. BOSE . . .	1. The Igneous Rocks of Darjiling and Sikkim.	Record.
" . . .	2. On the elevation and disturbance of the Sikkim Himalaya.	Record.
C. L. GRIESBACH . .	Geology of the Safed Koh .	Will appear in the Records, Geological Survey of India, for May next.

Report *on the* work *done in the* Laboratory *of the* Geological Survey of India *during* November, December 1891, *and* January 1892; *by* Thomas H. Holland, A.R.C.S., F.G.S., *Geological Survey of India.*

1. THE CONVERSION OF ANHYDRITE INTO GYPSUM.[1]

Since the publication of my note on the specimens of "gypsum" collected by Mr. Wynne in the Salt Range, I have had the privilege, through the kindness of Dr. Warth, of examining the original specimen to which Mr. Wynne refers in his memoir as containing, according to Dr. Warth's analysis, 5 per cent. of water.[2]

The results I have obtained confirm in every respect the evidence obtained from the specimens in the collection of the Survey Museum; and, at the same time, explain clearly the suggestion made by Mr. Wynne as to the composition of the hard nodules in the Salt Range gypsum.

If the analyses of the hard nodules had given a constant result of 5 per cent. of

[1] A continuation of "Chemical and Physical Notes on Rocks from the Salt Range, Punjab," by the same author, Rec., Geol. Surv. of India, Vol. xxiv, p. 235.

[2] Mem., Geol. Surv. of India, Vol. xiv, p. 74.

water within the reasonable variations attributable to inaccuracies of experimental methods, Mr. Wynne's suggestion of the existence of a compound like "semi-anhydrite' would be a most natural one. But, whilst I find the specimen analysed by Dr. Warth contains, as he states, about 5 per cent. of water, that result is true *only for the portion of the specimen from which Dr. Warth obtained his fragment for analysis.* All other parts of the specimen exhibit variations in composition in the same irregular way as those already in the collection, and which I have described in my note.[1] If Dr. Warth had, therefore, taken a second fragment for analysis instead of repeating his experiments on the 1st piece, the results would have been widely different. The following results have been obtained in the examination of separate fragments taken from the original specimen analysed by Dr. Warth.[2]

Four fragments were broken off — two from the fresh surface from which Dr. Warth had evidently taken a piece for his analyses; the remaining two fragments were selected from other parts of the specimen.

The first two pieces, it will be seen, do not disagree greatly from Dr. Warth's analyses—

No.	Sp Gr. (*determined.*)	Mineral composition. (*Calculated from Sp. Gr.*)		Chemical composition. (*Calculated from Sp. Gr.*)		Percentage of water *determined by ignition.*
1	2·762	Anhydrite . . .	70·2	Sulphate of lime . .	93·7	
		Gypsum . . .	29·8	Water . . .	6·3	5·37
2	2·752	Anhydrite . . .	68·6	Sulphate of lime . .	93·4	
		Gypsum . . .	31·4	Water . . .	6·6	5·21
3	2·659	Anhydrite . . .	53·8	Sulphate of lime . .	90·3	
		Gypsum . . .	46·2	Water . . .	9·7	8·40
4	2·612	Anhydrite . . .	46·4	Sulphate of lime . .	88·8	
		Gypsum . . .	53·6	Water . . .	11·2	10·02

A qualitative chemical analysis made by Mr. T. R. Blyth shows the rock to be composed almost wholly of sulphate of lime and water. Mr. Blyth has found no trace of magnesia, but carbonate of lime sometimes occurs in minute quantities. As in the results obtained during the examination of the other specimens, the water found by ignition is invariably less than that calculated from the specific gravity of the fragment.

I have examined, under the microscope, sections of Dr. Warth's specimen and

[1] Rec., Geol. Surv., Ind., Vol. xxiv (1891), pp. 235-44, and plates I and II.

[2] The method adopted is precisely that described in my former note (*loc cit*, p. 236)—the piece having its specific gravity first determined is crushed and *the whole* of the powder used in analysis.

they agree precisely with the description given in the previous number of the Records, of Mr. Wynne's specimens. Crystals of anhydrite, with characteristic cleavage and twinning, are imbedded in gypsum.

The same disposal of the constituents to produce an ophitic structure[1] characterizes the sections of this rock; and the same tendency to a schistose arrangement of the anhydrite-fragments, due undoubtedly to the hydration of the sulphate of lime, and coincident expansion to form gypsum.

Although I think there is now no doubt concerning the derivation of these gypseous masses from anhydrite, there seems no reason why the anhydrite may not have been simply de-hydrated gypsum. Upon this point the facts obtained in the laboratory can offer no evidence, and it becomes a question for the workers in the field to decide. I can only say that the gypsum is not of immediate sedimentary origin, and this agrees so far with the conclusions of Mr. Middlemiss as to the origin of the salt-marl.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1891 and January 1892.

Substance.	For whom.	Result.
Coal, for assay . .	P. GISBORNE & Co., Calcutta.	Proximate analysis and calorific power determined.
4 specimens of quartz, for gold.	BARRY & Co., Calcutta .	Assayed for gold.
1 specimen of quartz, for gold.	Ditto . .	Ditto.
Coal, from Kasaullia valley, 2 miles east of Kalka, for assay.	C. L. GRIESBACH, Geological Survey of India.	Quantity received . . 8 lbs. Moisture . . . 1.24 Volatile matter . . 16.52 Fixed carbon . . . 37.82 Ash . . . . 44.42 100.00 Cakes strongly. Ash—dark red.

[1] In using the term "ophitic," I am aware of the fact that the ophitic structure of igneous rocks and the structure of these anhydrite-gypsum rocks are widely different in origin. The occurrence of a schistose arrangement of the anhydrite, together with this so-called intergrowth of 'ophitic' gypsum is worthy of note as an indication of the fact that the gypsum is younger than the anhydrite, being, in fact, derived at the expense of the latter mineral. A somewhat analogous arrangement is conceivable in an igneous rock: a basic magma with porphyritic crystals of felspar might be irrupted as a dyke, and, cooling under conditions of quiescence give rise to an ophitic disposal of augite around the minerals previously consolidated, whilst the felspars (*porphyritic*, of Rosenbusch) are arranged in directions parallel to the face of the dyke or direction of flow. Such a case I have described from amongst the rocks collected by Mr. Gowland in Korea (*Quart. Journ., Geol. Soc.*, vol. XLVII (1891), p. 185). Notwithstanding the points of difference in these structures, I do not feel justified in suggesting a separate name for the structure of the anhydrite-gypsum rock.

Substance.	For whom.	Result.
Quartz, with galena, for gold and silver.	BARRY & Co, Calcutta .	Assayed for gold and silver.
Alluvial earth, for gold .	J. T. BABONAU, Sub-Divisional Officer, Palamow.	Contains no gold—the shining particles referred to are minute scales of mica.
Quartz, for gold . .	BARRY & Co., Calcutta .	Assayed for gold.
2 specimens of quartz, for gold.	H. T. IVATT, Coonoor, Nilgiris.	Ditto.
2 specimens of minerals, for determination.	F. ANDERSON, Lohardugga.	Augite—large crystals. Magnetite, hæmatite, and titanoferrite in schist.

Notifications by the Government of India during the months of November and December 1891 and January 1892, published in the "Gazette of India," Part I.—Appointment Confirmation, Promotion, Reversion and Retirement.

Department.	Number of order and date.	Name of officer.	From	To	Nature of Appointment, &c.	With effect from	Remarks.
Revenue and Agricultural Department.	$\frac{2664}{8}$, Surveys, dated 10th December 1891.	R. D. Oldham	Deputy Superintendent, 1st grade	Superintendent.	Substantive.	1st October 1891.	

Notification by the Government of India during the months of November and December 1891, and January 1892, published in the "Gazette of India," Part I.—Leave.

Department.	Number of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	Remarks.
Revenue and Agricultural Department.	$\frac{2554}{8}$, Surveys, dated 26th November 1891.	T. H. D. LaTouche.	Furlough .	24th May 1891.	7th November 1891.	

Annual Increments to graded Officers sanctioned by the Government of India during August, September and October 1891.

Name of Officer.	From	To	With effect from	No. and date of sanction.	Remarks.
T. H. D. LaTouche . .	R 620	R 600	1st April 1891.	Revenue and Agricultural Department, No. $\frac{2515}{30}$, Surveys, dated 21st November 1891.	
C. S. Middlemiss . .	580	620	1st November 1891.	Revenue and Agricultural Department, No 2497, Surveys, dated 18th November 1891.	
F. Noetling . . .	620	660	1st October 1891.	Revenue and Agricultural Department, No. $\frac{2709}{36}$, Surveys, dated 17th December 1891.	

Postal and Telegraphic Addresses of Officers.

Name of officer.	Postal address.	Nearest Telegraph office.
T. W. H. Hughes . . .	Mergui	Tavoy.
C. L. Griesbach . . .	Bhamo	Bhamo.
R. D. Oldham	Calcutta	Calcutta.
P. N. Bose	Mergui	Tavoy.
T. H. D. LaTouche . . .	Dera Ismail Khan . .	Dera Ismail Khan.
C. S. Middlemiss . . .	Abbottabad . . .	Abbottabad.
W. B. D. Edwards . . .	Do. . . .	Do.
P. N. Datta	Thayetmyo . . .	Thayetmyo.
F. Noetling	Mogaung . . .	Mogaung.
Hira Lal	Abbottabad . . .	Abbottabad.
Kishen Singh	Dera Ismail Khan . .	Dera Ismail Khan.

DONATIONS TO THE MUSEUM.

FROM 1ST NOVEMBER 1891 TO 31ST JANUARY 1892.

2 specimens of asbestos, from Banswarra, Western Malwa.

PRESENTED BY RAGHONATH RAO YADOW BHAGVAT, SECRETARY, COUNCIL OF REGENCY, GWALIOR STATE.

Large sheets of mica in crystals, and sheets cut for the market, and smaller crystals of mica and pegmatite from Inikurti and Utkoor, Nellore district.

PRESENTED BY E. H. SARGENT, INIKURTI.

Crystals of garnet and apatite, from Nellore.

PRESENTED BY J. H. BROUGHAM, CONSERVATOR OF FORESTS, NELLORE.

ADDITIONS TO THE LIBRARY.

FROM 1ST OCTOBER TO 31ST DECEMBER 1891.

Titles of Books. *Donors.*

BLACKBURN, *Charles F.*—Hints on Catalogue Titles and on Index Entries, with a rough vocabulary of terms and abbreviations, chiefly from Catalogues, and some passages from journeying among books. 8° London, 1884.

DARWIN, *C.*—A Naturalist's Voyage round the World in H. M.'s Ship "*Beagle.*" 8° London, 1890.

DAWSON, *Sir J. W.*—Geology of Nova Scotia, New Brunswick and Prince Edward Island, or Acadian Geology. 8° London, 1891.

DITTE, *Alfred.*—Leçons sur les Métaux Professées à la Faculté des Sciences de Paris. Fasc I. 4° Paris, 1891.

GEIKIE, *Archibald.*—Class-Book of Geology. 8° London, 1891.

GEIKIE, *Archibald.*—Outlines of Field Geology. 8° London, 1891.

GÜNTHER, *Dr. Siegmund.*—Handbuch der Mathematischen Geographie. 8° Stuttgart, 1890.

HEILPRIN, *Angelo.*—The Geographical and Geological Distribution of Animals. 8° London, 1887.

HETTNER, *Dr. Alfred.*—Gebirgsbau Und Oberflächenges taltung der Sächsischen Schweiz. 8° Stuttgart, 1887.

HOLMES, *Thomas Vincent* and SHERBORN, *C. Davies.*—A Record of Geological Excursions made between 1860 and 1890. 8° London, 1891.

KLEIN, *Dr. H. J.*—Jahrbuch der Astronomie und Geophysik. I. Jahrgang 1890. 8° Leipzig, 1891.

KUNTZ, *G. F.*—Gems and Precious Stones of North America. 4° New York, 1890.

LOCKYER, *J. N.*—Studies in Spectrum Analysis. 8° London, 1886.

MARCOU, *Jules.*—Autobiographical Notice of Ebenezer Emmons. 8° Pam., 1891.
THE AUTHOR.

MARCOU, *Jules.*—Geology of the Environs of Quebec, with Map and Sections. 8° Pam., 1891. THE AUTHOR.

Titles of Books. *Donors.*

NEHRING, *Dr. Alfred.*—Ueber Tundren und Steppen der Jetzt und Vorzeit mit besonderer Berucksichtigung ihner Fauna. 8° Berlin, 1890.

PRIEM, *Fernand.*—L'Evolution des Formes Animales avant l'apparition de l'homme 8° Paris, 1891.

RICHARDSON, *B. W*—Diary and Life of Thomas Sopwith. 8° London, 1891.

SCHELLEN, *Dr. H.*—Spectrum Analysis in its Application to Terrestrial Substances and the Physical Constitution of the Heavenly Bodies. 2nd Edition. 8° London, 1885.

SOLMS-LAUBACH, *H. Grafzu.*—Fossil Botany, being an introduction to Palaeophytology from the Standpoint of the Botanist. 8° Oxford, 1891.

STEINHAUSER, *Anton.*—Grundzüge der Mathematischen Geographie und der Landkarten Projection. 8° Wien, 1887.

TRYON, *George W.*—Manual of Conchology. Vol. XII, part 49; and 2nd series, Vol. VI, part 25. 8° Philadelphia, 1891.

TYNDALL, *John.*—The Forms of Water in Clouds and Rivers, Ice and Glaciers. 10th Edition. 8° London, 1889.

PERIODICALS, SERIALS, &c.

American Journal of Science. 3rd series, Vol. XLII, Nos. 250-251. 8° New Haven, 1891. THE EDITORS.

American Naturalist. Vol. XXV, Nos. 294-296. 8° Philadelphia, 1891.

Annalen der Physik und Chemie. Neue Folge, Band XLIV, heft 2-3. 8° Leipzig, 1891.

Annales de Géologie et de Paléontologie. Livr. 9. 4° Palerme, 1891.

Annales des Sciences Géologiques. Tome XXI. 8° Paris, 1891.

Annals and Magazine of Natural History. 6th series, Vol. VIII, Nos. 46-48. 8° London, 1891.

Athenæum. Nos. 3334-3345. 4° London, 1891.

Beiblätter zu den Annalen der Physik und Chemie. Band XV, Nos. 4 and 8-10. 8° Leipzig, 1891

Chemical News. Vol. LXIV, Nos. 1660-1671. 4° London, 1891.

Colliery Guardian. Vol. LXII, Nos. 1603-1614. Fol. London, 1891.

Geological Magazine. New series, Decade III, Vol. VIII, Nos. 10-11. 8° London, 1891.

Indian Engineering. Vol. X, Nos. 14-24 and 26. Flsc. Calcutta, 1891. PAT. DOYLE.

Iron. Vol. XXXVIII, Nos. 975-986. Fol. London, 1891.

London, Edinburgh, and Dublin Philosophical Magazine, and Journal of Science. 5th series, Vol. XXXII, Nos. 197-199. 8° London, 1891.

Mining Journal. Vol. LXI, Nos. 2925-2936. Fol. London, 1891.

Nature. Vol. XLIV, No. 1142 to Vol. XLV, No. 1153. 4° London, 1891.

Neues Jahrbuch für Mineralogie, Geologie und Palæontologie. Jahrg. 1891, Band II, heft 3. 8° Stuttgart, 1891.

Repertorium zum Neuen Jahrbuch für Mineralogie, Geologie und Palæontologie für die Jahrgänge, 1885-1889, und die Beilage-Bände III-VI, Von. Dr. Leopold van Werveke. 8° Stuttgart, 1891.

Titles of Books. *Donors.*

Petermann's Geographischer Mittheilungen. Band XXXVII, Nos. 9-11. 4° Gotha 1891. THE EDITOR.

The Indian Engineer. Vol. XII, Nos. 234-244 and 246. Flsc. Calcutta, 1891. J. McINTYRE.

GOVERNMENT SELECTIONS, REPORTS, ETC.

BOMBAY.—Brief Sketch of the Meteorology of the Bombay Presidency, 1890-91. Flsc. Bombay, 1891. METEOROLOGICAL REPORTER, BOMBAY.

" Selections from the Records of the Bombay Government. New series, No. 202. Flsc. Karachi, 1891. BOMBAY GOVERNMENT.

INDIA.—Administration Report of the Baluchistan Agency for 1889-90. Flsc. Calcutta 1891. FOREIGN DEPARTMENT.

" Administration Report of the Persian Gulf Political Residency and Muscat Political Agency for 1890-91. Flsc. Calcutta, 1891. FOREIGN DEPARTMENT.

" Selections from the Records of the Government of India, Foreign Department, Nos. 278 and 280. Flsc. Calcutta, 1891. FOREIGN DEPARTMENT.

" History of Services of Officers holding Gazetted appointments in the Home, Foreign, Revenue and Agricultural, and Legislative Departments, corrected to 1st July 1891. 8° Calcutta, 1891. GOVERNMENT OF INDIA.

" List of Civil Officers holding Gazetted appointments under the Government of India, in the Home, Legislative, Foreign, and Revenue and Agricultural Departments, corrected to 1st July 1891. 8° Calcutta, 1891. GOVERNMENT OF INDIA.

" List of Officers in the Survey Department and in the offices of the Meteorological Reporter to the Government of India; Trustees, Indian Museum; Reporter on Economic Products; Director, Botanical Department, Northern India; and General Superintendent, Horse-Breeding Department; corrected to 1st July 1891. 8° Calcutta, 1891. GOVERNMENT OF INDIA.

" Quarterly Indian Army List. New series, No. 9. 8° Calcutta, 1891. GOVERNMENT OF INDIA.

" Report on the explorations of Sikkim, Bhutan, and Tibet. Flsc. Dehra Dun, 1889.

" Statement showing quantities and values of Minerals and Gems produced in each British Province and Native State of India during the calendar year 1890. Flsc. Calcutta, 1891. REVENUE AND AGRICULTURAL DEPARTMENT.

TRANSACTIONS, PROCEEDINGS, ETC., OF SOCIETIES, SURVEYS, ETC.

BATAVIA.—Dagh-Register gehonden int Casteel, Batavia, vant passerende daer ter plaetse als over geheel Nederlandts-India Anno 1663. Van J. A. Van Der Chijs. 8° Batavia, 1891. BATAVIAN SOCIETY.

Titles of Books. *Donors.*

BATAVIA.—Notulen van het Bataviaasch Genootschap van Kunsten en Wetenschappen. Deel XXIX, afl. 2. 8° Batavia, 1891. BATAVIAN SOCIETY.

„ Tijdschrift voor Indische Taal—Land-en Volkenkunde. Deel XXXIV, afl. 6. 8° Batavia, 1891. BATAVIAN SOCIETY.

BERLIN.—Zeitschrift der Deutschen Geologischen Gesellschaft. Band XLIII, heft 2. 8° Berlin, 1891. THE SOCIETY.

BOSTON.—Proceedings of the Boston Society of Natural History. Vol. XXV, Part 1. 8° Boston, 1891. THE SOCIETY.

BRISBANE.—Annual Report of the Trustees of the Queensland Museum for 1890. Flsc. Brisbane, 1891. THE MUSEUM.

„ Proceedings and Transactions of the Queensland Branch of the Royal Geographical Society of Australia. Vol. VI, Part II. 8° Brisbane, 1891. THE SOCIETY.

BRUSSELS.—Bulletin de la Société Royale Belge de Géographie. Année XV, No. 5. 8° Bruxelles, 1891. THE SOCIETY.

CALCUTTA.—Archæological Survey of India. The Monumental Antiquities and Inscriptions in the North-Western Provinces and Oudh, described and arranged by A Führer, PH D. 4° Allahabad, 1891.
THE NORTH-WESTERN PROVINCES AND OUDH GOVERNMENT.

„ Epigraphia Indica and Record of the Archæological Survey of India. Part VIII. 4° Calcutta, 1891. THE SURVEY.

„ Proceedings of the Asiatic Society of Bengal. No. 9. 8° Calcutta, 1891. THE SOCIETY.

„ Survey of India Department Notes for September and October 1891. Flsc. Calcutta, 1891. SURVEY OF INDIA.

CAMBRIDGE.—Proceedings of the Cambridge Philosophical Society. Vol. VII, part 4. 8° Cambridge, 1891. THE SOCIETY.

CAMBRIDGE, *Mass.*—Bulletin of the Museum of Comparative Zoology. Vol. XVI, No. 10. 8° Cambridge, Mass., 1891. THE MUSEUM.

DUBLIN.—Scientific Proceedings of the Royal Dublin Society. New series, Vol. VI, part 10, and VII, parts 1-2. 8° Dublin, 1891. THE SOCIETY.

„ Scientific Transactions of the Royal Dublin Society. Series II, Vol IV, parts 6-8. 4° Dublin, 1891. THE SOCIETY.

EDINBURGH.—Scottish Geographical Magazine. Vol. VII, Nos. 10-12. 8° Edinburgh, 1891. SCOTTISH GEOGRAPHICAL SOCIETY.

FRANKFORT.—Abhandlungen von der Senckenbergischen Naturforschenden Gesellschaft. Band XVI, heft 3-4. 4° Frankfort-ã-M., 1891.

GENEVA.—Mémoires de la Société de Physique. Tome XXI, part 1. 4° Genève, 1890-91. THE SOCIETY.

LAUSANNE.—Bulletin de la Société Vaudoise des Sciences Naturelles. 3^{me} série, Vol. XXVII, No. 104. 8° Lausanne, 1891. THE SOCIETY.

LEIDE.—Annales de l'Ecole Polytechnique de Delft. Tome VII, liv. 1. 4° Leide, 1891. L'ECOLE POLYTECH., DELFT.

LEIPZIG.—Wissenschaftliche Veröffentlichungen des Vereins für Erdkunde zu Leipzig. Band 1. 8° Leipzig, 1891. THE SOCIETY.

Titles of Books. *Donors.*

LONDON.—Journal of the Society of Arts. Vol. XXXIX, No. 2026 to Vol. XL, No. 2036. 8° London, 1891. THE SOCIETY.

" Philosophical Transactions of the Royal Society of London. Vol. 181 A and B. With List of Fellows. 4° London, 1891. THE SOCIETY.

" Proceedings of the Royal Society of London. Vol. L, No. 302. 8° London, 1891. THE SOCIETY.

" Proceedings of the Royal Geographical Society. New series, Vol. XIII, No. 9. 8° London, 1891. THE SOCIETY.

" Proceedings of the Zoological Society of London. Parts II and III. 8° London, 1891. THE SOCIETY.

" Transactions of the Zoological Society of London. Vol. XIII, part 3. 4° London, 1891. THE SOCIETY.

" Quarterly journal of the Geological Society. Vol. XLVII, No. 188. With List of Fellows. 8° London, 1891. THE SOCIETY.

" Systematic List of British Oligocene and Eocene Mollusca in the British Museum. 8° London, 1891. THE MUSEUM.

MADRID.—Boletin de la Sociedad Geografica de Madrid. Tome XXXI, Nos. 1—3. 8° Madrid, 1891. THE SOCIETY.

MANCHESTER.—Memoirs and Proceedings of the Manchester Literary and Philosophical Society, 1890-91. 4th series, Vol. IV, Nos 4—5. 8° Manchester, 1891, THE SOCIETY.

MELBOURNE.—Reports and Statistics of the Mining Department, Victoria, for the quarter ending 30th June 1891. Flsc. Melbourne, 1891. MINING DEPARTMENT, VICTORIA.

OXFORD.—Catalogue of books added to the Radcliffe Library, Oxford University Museum, during the year 1890. 4° Oxford, 1891. THE MUSEUM.

PARIS.—Annales des Mines. 8^me^ série, Tome XIX, livr. 3 8° Paris, 1891. DEPARTMENT OF MINES, PARIS.

" Bulletin de la Société Géologique de France. 3^me^ série, Tome XVIII, No. 9, and XIX, No. 6. 8° Paris, 1889-90. THE SOCIETY.

" Compte Rendu des Séances de la Société de Géographie. Nos. 16—17. 8° Paris, 1891. THE SOCIETY.

PHILADELPHIA.—Journal of the Franklin Institute. Vol. 132, Nos. 3—5. 8° Philadelphia, 1891. THE INSTITUTE.

QUEBEC.—Transactions of the Literary and Historical Society of Quebec. No. 20. Sessions of 1889 to 1891. 8° Quebec, 1891. THE SOCIETY.

ROME.—Atti della Reale Accademia dei Lincei. Série IV, Rendiconti, Vol. VII, Semestre II, fasc. 4—8. 8° Roma, 1891. THE ACADEMY.

ST. PETERSBURG.—Memoires de l'Académie Impériale des Sciences. Tome XXXVIII, No. 3. 4° St. Petersburg, 1891. THE ACADEMY.

SYDNEY.—Annual Report of the Department of Mines, New South Wales, for the year 1890. Flsc. Sydney, 1891. DEPARTMENT OF MINES, NEW SOUTH WALES.

" Proceedings of the Linnean Society of New South Wales. 2nd series, Vol. VI, part 1. 4° Sydney, 1891. THE SOCIETY.

" Records of the Australian Museum. Vol. I, Nos. 8—9. 8° Sydney, 1891. THE MUSEUM.

Titles of Books	*Donors.*
VIENNA.—Verhandlungen der K. K. Geologischen Reichsanstalt. Nos. 8 to 14. 8° Wien, 1891.	THE INSTITUTE.
WASHINGTON.—Annual Report of the Board of Regents of the Smithsonian Institution to July 1889 8° Washington, 1890.	THE INSTITUTION.
WELLINGTON.—Reports on the Mining Industries of New Zealand, 1891. Flsc Wellington, 1891.	MINING DEPARTMENT, NEW ZEALAND.

MAPS.

PARIS — Carte Géologique détaillée de la France. Sheets 28, 89, 105, and 183. Map, Paris, 1891.	GEOLOGICAL SURVEY OF FRANCE.

Govt. of India Central Printing Office.—No. 41 D. G. Survey.—10-3-92 —636

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1892. [August.

Note on the Locality *of* Indian Tscheffkinite, *by* F. R. MALLET, *late Superintendent, Geological Survey of India.*

The rare and interesting mineral, from Southern India, subsequently identified as tscheffkinite, was obtained by M. Leschenault de la Tour in 1817 or 1818, during his travels for the Muséum d'histoire naturelle at Paris. Occupied mainly in botanical and zoological pursuits, M. Leschenault appears to have been able to give but a secondary place to geology and mineralogy, and some, at least, of the minerals he obtained were identified, not by himself in the field, but by others in the laboratory many years later. Amongst these were the tscheffkinite specimens, the nature of which, indeed, could not have been ascertained without analysis, as the mineral was, previous to the examination of Leschenault's specimens, entirely unknown. Its outward appearance is not strikingly suggestive of any peculiar interest, and hence, perhaps, the fact that in the account of his journey[1] there is no allusion of any kind to the substance in question, and, consequently, no direct indication of the locality where it was found. But it seems at least equally, if not more, likely that this omission is due to M. Leschenault having not obtained the specimens himself *in situ*, but been given them by M. Healt (*sic*),[2] concerning whom he writes[3]—" My mineralogical collection has been principally enriched by the gifts of M. Healt, adjunct and brother-in-law of M. Carpenter, commercial

[1] Rélation d'un voyage à Karikal et à Salem ; *Mémoires du Muséum d'histoire naturelle*, t. VI (1820), p. 329.

[2] Is this the Mr Heath who, some years later, was connected with the Porto Novo Iron works, and who has left an account of the Salem ores which were smelted there ?

[3] *Op. cit.*, p. 344.

resident" (at Salem). "He collects everything of mineralogical interest that is obtainable in the country, and he has had the goodness to give me many specimens of corundum, the ore of native iron,[1] garnets," etc.

The substance was first analysed by Langier in 1825, who calls it merely "un minéral noir de la côte de Coromandel."[2] This extremely vague, and, as it now appears, incorrect, locality has since then been assigned to it by mineralogical authors generally. The rarity of the mineral, which seems to have been found in only three places,—Southern India, the Urals, and Virginia—in none of which more than a few specimens have been obtained, makes it desirable that the spot in India where it occurs should be accurately known; the more so as very few indeed of Leschenault's specimens of it are now forthcoming. I have been lately informed by M. A. Lacroix that none are to be found in any of the public collections of Paris. There is, however, a small piece in the British Museum at South Kensington, with a written label underneath it, which I copied some years ago, and which runs as follows:—"Minéral brun de Coromandel (Beudant, p. 652).—Fragment du morceau rapporté par Leschenault et analysé par Langier, *Loc.*, Kantamala, Côte de Coromandel, parait être une vraie Tscheffkinite d'après la nouvelle analyse encore inachevée de M. Damour (Juillet, 1861)."[3] When writing Part IV of the Manual of the Geology of India, in Calcutta, I was unable to trace the position of Kantamala. I had not access then to Leschenault's original memoir, which now lies before me, It does not contain very much geological information, and, as previously remarked does not allude to anything resembling tscheffkinite. But on page 344 there is the following passage:—"At about two leagues[4] to the south-south-west of Salem, in the mountain of Kantiamalé, there is a sandy iron-ore that is collected in the ravines. It is very rich. The iron that is smelted from it produces an excellent steel."[5]

I do not think anyone conversant with the latitude that obtains in the spelling of Indian names, and specially in those of Southern India, will feel much doubt that 'Kantamala' of the British Museum label, and 'Kantiamalé,' are the same. It is true that 'Kantiamalé' is not on the Coromandel coast, but in the Salem district. But exactly the same mistake was made by Count de Bournon in relation to Leschenault's specimens of indianite, which he described as from Salem "on the coast of Coromandel."[6] Nor is the mistake confined to indianite, for M. Lacroix notices that "the rocks and minerals included in de Bournon's collection are labelled as coming from Salem 'on the Coromandel coast,' although Salem is over 100 miles from the sea."[7] Whether the error originated with him, or was merely accepted by him on the authority of some one else, is not clear; but it is

[1] That is to say, the ore used in the native smelting furnaces.

[2] *Mém. du Muséum d'hist. nat.*, t. XII (1825), p. 189.

[3] The label is on a form with the name of M. Saemann printed at the top. The specimen, therefore, appears to have come from his collection, and, presumably, was in that of M. Cordier still earlier.—See footnote, p. 125.

[4] Say about 5 miles:

1 old French posting-league = 2·42 Eng. miles.
1 „ league of 25 to 1 degree = 2·76 Eng. miles.

[5] There follows a short outline of the native method of steel-making, but, as it does not differ from that given in much more detail by other writers, it is not worth quoting here.

[6] Observations sur quelquesuns des minéraux, soit de Ile de Ceylan, soit de la Côte de Coromandel, 1823.

[7] *Bulletin de la Société Française de Minéralogie*, t. XII, p. 282.

not likely to have been made by Leschenault himself, who was familiar with the district.[1]

It only remains, then, to identify the 'mountain of Kantiamalé.' I have carefully examined sheets 61 and 79 of the Indian Atlas (1 inch = 4 miles), and the Revenue Survey map of Salem taluq (1 inch = 1 mile), within a radius of 8 or 10 miles round Salem, without finding the name in question, the only names at all like it are, Keddamalai hill (spelt Keddmally on atlas sheet), 10 miles south-east from Salem, and Kanjamalai hill (Kunjamullay of atlas sheet), the culminating peak of which (3,238 feet) is 7 miles, and the eastern end of the principal ridge 5 miles, west-south-west from Salem. Kanjamalai hill[2] is composed of metamorphic rocks, which form a great synclinal and include three splendid beds of magnetic iron-ore, the ore has been worked by the natives from time immemorial, a portion of the iron produced being converted into wootz steel. This is, I think beyond all reasonable doubt, the mountain containing rich iron-ore referred to by M. Leschenault. The terminations *malé* and *malai* (meaning *mountain*) are evidently the same, and in the rest of the words (Kantia and Kanja) there is a difference of but one important letter—a difference which may easily have arisen from M. Leschenault having failed to catch the correct pronunciation, or through some clerical error.[3] There is also a difference in bearing, Kantiamalé, being described as about 5 miles south-south-west from Salem, while Kanjamalai is the same distance west-south-west. I do not think this is of much importance, however, considering how frequently errors in bearing creep in.[4]

There are some small unnamed hills marked on the maps in the exact position mentioned by Leschenault, and it might be surmised that one of these is Kantiamalée. But, besides the fact that he speaks of a *mountain*, if there were important deposits of iron-ore in the two adjacent positions, it is unlikely that Leschenault would have ignored the celebrated ones of Kanjamalai, and highly improbable that Messrs. King and Foote would have ignored those at Kantiamalé.

Kanjamalai hill being within 5 miles of Mr. Healt's residence, was doubtless very thoroughly explored by him, and it seems most probable that he found the tscheffkinite there, and gave specimens of it to M. Leschenault, who may have derived his information about the hill from the same source.

If the above conclusion as to the spot where such an interesting mineral occurs be accepted, it is to be hoped that an attempt will be made to re-discover it, and learn something as to its mode of occurrence.

It may perhaps be worth remark here that Langier's analysis, which, as it

[1] Leschenault's collection was in the Muséum d'histoire naturelle at the time Langier's analysis was made, but one or more specimens of tscheffkinite seem to have been also in the possession of M. Cordier (Professor of Geology in the Museum, as Langier was Chemist), from whom they passed to M. Saemann, who gave Damour the piece analysed by him. It seems probable that some, at least, of the tscheffkinite passed through de Bournon's hands at the time he examined Leschenault's specimens of indianite, corundum, etc.

[2] A detailed description of which is given by Messrs. King and Foote in the Memoirs of the Survey, vol. iv, p. 379.

[3] An analogous case, where "I" has been supplanted by "S," might be adduced in the error by which, during 40 years, the so-called mineral Jyepoorite figured as Syepoorite (*vide* vol. xiv, p. 192).

[4] *e.g.*, Ganypittah is described by Dr. Heyne as west of Ongole, instead of south-west (vol. xii, p. 168).

appears in mineralogical text-books, is copied from Beudant's *Traité de Minéralogie*, 2nd edition (1832), is incorrectly given in that work. It stands in the original memoir[1] as follows:—

Oxide of cerium	36·5
Oxide of iron	19·8
Silica	19
Lime	8
Alumina	6
Water	11·05
Oxide of manganese	1·20
Oxide of titanium	8
	109·38 (*sic*)

The excess, M. Langier adds, is due to the cerium and iron having been weighed as peroxides, while they exist in the mineral as protoxides. Their percentages should therefore be diminished to 31·1 and 15·4 respectively, the total being thus reduced to 99·25 (*sic*).

Comparatively recently tscheffkinite has been found in Nelson Co., Virginia, and analysed by R. C. Price.[2] In discussing the results he says:—" When considering the cerium earths as protoxides, tscheffkinite was classified by Dana as a subsilicate with titanic oxide basic; the oxygen ratio for $SiO_2 : TiO_2 : R_2O_3 : RO = 5 : 4 : 2 : 4$. With these earths and sesquioxides, the above must be rejected; and in order to consider the published analyses of tscheffkinite (1) and (4), I have assumed the cerium earths to exist in the same proportions as have been found in the present specimen,[3] which affords oxygen ratios for them as follows:—

	SiO_2	TiO_2	R_2O_3	RO
" (1) Ilmen	77	55	44	25
(4) Coromandel	77	64	44	24
Nelson Co.	78	62	40	28

" From the inspection of these figures it appears highly probable that the titanic oxide should be regarded as replacing silica. The composition of the Nelson Co. mineral approximates to—

$$\text{“ } 2\,(Ca, Be, Fe, Mg)\,O, (Ce, Di, La, Fe)_2\,O_3.\ 5\,(Si, Ti)O_2$$

and the formula of each of the above will fairly correspond to a bisilicate of the amphibole group, with silicon replaced by titanium."

Another analysis of Virginia tscheffkinite (from Bedford Co.) has been made by L. G. Eakins,[4] who remarks that " the molecular ratios seem to lead to no definite or satisfactory formula—a result quite in accordance with the evidence furnished by the microscopical examination of sections." Microscopic examination showed the

[1] *Op. cit.*, p. 194.

[2] *American Chemical Journal*, vol. x (1888), p. 38.

[3] Damour thought that didymium and lanthanum were present, together with the cerium, in the Indian tscheffkinite (Dana's System of Mineralogy, p. 388).

[4] *Amer. Jour. Sci.*, vol. xlii (1891), p. 36.

transparent, amorphous, apparently original, material to have partially decomposed into an opaque ochreous matter, besides which there were bands of various secondary minerals visible. A sample of Price's tscheffkinite showed an almost identical structure under the microscope. Mr. Eakins therefore concludes that tscheffkinite is not a true mineral, but only a mixture. A somewhat similar opinion seems to have been held by Des Cloizeaux about the Indian tscheffkinite, in respect to which he writes[1]—" The material is not perfectly homogeneous, for I have observed with the microscope that it is composed of a brown mass, without any action on polarised light, in which are included very small, colourless, strongly birefringent grains."

Geological Sketch *of the* country north of Bhamo, *by* C. L. GRIESBACH, C. I. E., *Superintendent, Geological Survey of India.*

Geology.

East and north-east of Bhamo a series of hill ranges, all more or less parallel to each other, forms a compact mountain system, which has been traced to far north of the Maikha branch of the Irrawaddi by Major Hobday and others, and which in some way, not known to us exactly, is most probably linked to the north-eastern extension of the Himalayan system. It forms the natural frontier between Burma and China, but not the *watershed* between the former country and Yunnan, which has not been explored yet. This system of ranges rises to considerable heights (8,000 to 9,000 feet) and possesses an average direction of strike from south to north and north-east, a direction which coincides as I have ascertained with the general direction of the strike of the strata forming these ranges.

The mountain system is crossed by several transverse valleys; as, for instance, the Maikha branch of the Irrawaddi, the Taiping, etc.

As far as it was possible to discover during the very rapid traverses made by Dr. Noetling and myself, it appears that the entire area north of Bhamo is formed by a succession of flexures of older rocks, all striking more or less north and south and north-east to south-west, which flexures have been extensively eroded by the Upper Irrawaddi drainage.

Several larger synclinal troughs, or rather areas of depression, have been formed when the beds composing the country north of Bhamo were compressed into folds; such, for instance, is probably the area of the Indawgyi lake basin and also the broad valley of the Irrawaddi between Hokat and Watu.

The principal formations found in the Northern Bhamo district are the following:—

1. Metamorphic, including probably the palæozoic group.
2. Mesozoic strata.
3. Tertiary beds.
4. Igneous rocks.

It has been ascertained that by far the greatest part of the ground explored by

[1] Manuel de Minéralogie, t. i, p. 554.

us during the last field season is formed of crystalline (metamorphic) rocks; amongst which a coarse, porphyritic gneiss is very characteristic in the eastern part of the area reported on, and it was also met with by Dr. Noetling in the Mogaung area.

Metamorphic rocks.

Besides the gneissic rocks, there are also schistose rocks, phyllites and hornblendic rocks.

The whole group of metamorphic rocks has evidently undergone most extensive folding and crumpling, with subsequent erosion; but it is now so extensively obscured by sub-recent deposits and vast forests, that it will, for a long time to come, be next to impossible to arrive at any closer knowledge of the sequence of the series.

But it appears probable that certain more or less crystalline rocks, chiefly limestones, which occur in the midst of the metamorphic flexures, and seemingly conformably to the latter, belong to the palæozoic groups and are possibly silurian, though actual proofs are wanting.

Palæozoics.

The only trace of mesozoic rocks consists in a pebble, containing an ammonite found by Dr. Noetling near the amber-mines. It is probably cretaceous and may have been derived from a tertiary conglomerate within the amber-mines formation.

Mesozoic strata.

Patches of sandstone, mostly highly disturbed, occur here and there, probably forming remnants only of a once much more extensive series of tertiary beds. Such are found in the Indawgyi lake district, west of Mogaung, in the Amber Mines district and in patches north of the "Confluence."

Tertiary formation.

These patches of tertiary formations may include members of several divisions of the system, but resemble mostly the miocene sandstone series of Upper Burma, and like the latter are characterised by the occurrence of patchy seams of poor lignitic coal.

The amber-mines (on which Dr. Noetling reports in detail) are situated within the area of tertiary deposits.

Widespread alluvial deposits, both fluviatile and lacustrine, occupy the wide troughs of the Irrawaddi and its minor confluents. From an economic point of view, perhaps the most important of these deposits is the widespread formation of clays, gravels, and sands filling the open trough through which the Irrawaddi flows between Watu and Hokat, and which is some 20 to 24 miles in width. This trough is partly filled by almost horizontally bedded deposits of clays and gravels chiefly, which are possibly of lacustrine origin, though merging upwards into deposits of fluviatile nature.

Younger tertiaries, including recent deposits.

The formation is of some economic importance, as it contains a not inconsiderable amount of gold disseminated throughout it in fine dust, to which reference is made below.

Parallel with the general strike of the lines of disturbance of the older rocks appear long strips of igneous rocks, which I believe have been intruded in fissures of dislocation.

Igneous rocks.

They are accompanied by numerous dykes and intrusions in the neighbouring rock-formations; and there is some economic interest attached toem, in as much as the mineral known in Burma as jade occurs in veins within these igneous intrusions, which, as far as I know, are all of basic rocks.

Broadly speaking, three principal lines of intrusion are found within the area here reported on, namely—

One, running almost due north and south along the 97° 30′ longitude to near the confluence: another forming the valley of the Irrawaddi, in the defile between Bhamo and Sinbo, and continued northwards along its right banks; the third belongs to the Jade Mines district.

B.—Economic Notes on the Upper Irrawaddi valley north of Bhamo.

Having briefly sketched the geological features of the hill ranges which bound the Irrawaddi river valley north-east of Bhamo and form our frontier with China, I may at once state that they are practically barren of all useful minerals. There are reports that lead ores occur, but I have not come across any during my journeys in these hills; and if they ever existed, they would be practically valueless.

The only minerals remaining to be noticed are the following :—

Coal.

The only traces of coal which occur within the area described here are found some 10 miles west of Mogaung, as noticed by Dr. Noetling; but they appear to be of little, if any, value.

Occasionally small quantities of coal (lignite) are brought to Myitkyina for sale. This mineral comes from the neighbourhood of Talang, north of the Pungin Kha, about 16 miles north-north-west of the confluence. From inquiries which I made of natives of that country, there is a seam of this coal there some 2 to 3 feet in thickness, which in any case would scarcely be good enough to work, and with wages as high as they are in those parts at present, is altogether valueless.

The Kachins sell this lignite at 8 annas a basket at Myitkyina, and it need scarcely be said that it would be cheaper to import English coal at this rate.

It was reported that coal was found between Ningrong and Kantaoyaung, some 24 miles due east of Ayainuama on the Irrawaddi, of which supposed coal specimens were forwarded to me. This proved to be not coal at all, but hornblendic rock.

Gold.

This metal is found in the form of fine grains and leaflets in the recent deposits of Irrawaddi valley and of all its tributaries.

Its presence is known to the natives, who wash these deposits after a fashion, and make thereby from about 4 to 12 annas per day a man. Their mode of washing for it is by means of wooden cradles, rarely more than 5 feet long by 2 feet wide. The natives are fairly efficient at this work, and would no doubt easily acquire a more modern mode of winning the precious metal, if put in the way of it. But nowhere have I noticed that they dig deep into the recent or sub-recent deposits for auriferous sands, although such must exist in lower depths most certainly. They usually collect only the most recent accumulations of sands and grit which are caught on the upper reaches of sandbanks in the river. That in such situations gold exists, and as I have seen myself, in well rounded, water-worn leaflets of minute size, proves that probably the river is even now cutting through an alluvial deposit which contains gold, and that the latter is re-deposited after floods on the sandbanks and projecting spits of land along the banks. It seems highly probable that within the thickness of the sub-recent gravels and clays of the Upper Irrawaddi a horizon may be found in which gold is more plentiful and which might pay if regularly mined for on a larger scale. Even as it is, the surface sands along

the banks contain probably not less than 30 grains of gold per ton of dirt, which would be good enough to pay working on a larger scale.

The only place where I saw natives digging deeper into the auriferous deposits was about 2 miles north of Myothit, north-east of Bhamo, where they have dug a trench several feet deep and some 40 to 50 feet long into much decomposed gneissic strata, which they wash for gold. The presence of gold in this rock must be in very finely disseminated form; and I have satisfied myself that in the last-mentioned locality there is no auriferous lode or reef, but that the gold occurs in the gneiss itself in very minute quantities. I have not seen nor even heard of any locality where gold occurred in reefs.

Spinel; rubies.

Major Hobday of the Survey of India reported the discovery by him of numerous crystals of spinel in the recent deposits near the junction of the Pungin Kha and Mali Kha, north of the confluence.

I myself have met with very minute fragments of such crystals in the sands and recent alluvium of the Irrawaddi below Myitkyina, where the heavy iron-sand which is left in the cradles along with the gold flakes when washing the sands for the latter, is often largely mixed with the fine splinters of spinel crystals. These increase in number and size higher up the Irrawaddi; and at Watu I have found large crystals of the same with millions of small fragments of the same; amongst them splinters which appear to me to be rubies, but are too small for certain determination. It is therefore certain that somewhere higher up the river, rock must be *in situ* which contains these minerals. The deposits near the Pungin Kha contain these crystals in the same manner as the alluvial gravels near Watu, and I have no doubt that they are derived from some metamorphic rock (perhaps crystalline limestone) still further north. It is a question well worth inquiring into, but this cannot be done until the country is much more accessible than it is now.

From the foregoing it appears, therefore, that there are widely extended alluvial deposits in the Upper Irrawaddi valley, which are already known to contain gold, spinel, and possibly also rubies. By far the greater part of the area which is formed by these alluvial deposits is practically a desert, as very few, if any, settlements exist there, and thus the country may be looked upon as a particularly favourable field of enterprise for mining purposes, if the labour difficulties could be overcome.

Preliminary Report *on the* economic resources *of the* Amber *and* Jade mines area *in* Upper Burma, *by* FRITZ NOETLING, PH.D., *Palæontologist, Geological Survey of India.*

Situation of the mines.

Amber.

The amber-mines which were examined by me are situated about 5 miles to the south-west of the village of Maingkhwan on a low isolated hill, which rises abruptly from the surrounding plains. There is no doubt that this hill, which has an elongated shape, the main axis running N.E.-S.W., formed part of a formerly wider extended river terrace, which has, however, been considerably denuded and worn away during the process of time. It is therefore *a priori* not improbable that amber may be

found also at other localities in that part of the country near the Nangotiemaw hill. I was subsequently informed that the amber-mines proper—that is to say, those which at present produce the amber—are situated west of, and are close to, a village called Lalaung.

Geology.

The strata in which the amber is found belong to the tertiary formation, probably to the lower miocene. The exact age cannot be stated yet, as no fossils have so far been discovered. The amber-bearing beds consist of a soft, blue clay, which is superficially discoloured brown, the discolouring being apparently due to the disintegrating action of organic acids formed by the extremely rich vegetation; and it may therefore be expected that the brown portion of clay forms only a thin covering of varying thickness on the exposed parts of the blue clay. It might further be anticipated that the amber found in this clay, being also under the influence of the chemical process which discoloured the clay, would be of inferior quality to that which is extracted from the blue clay. The experimental shafts sunk by me have proved that both these views are correct.

The clay is well stratified, and it reminds me very much of the blue, coal-bearing clay of the Chindwin coal-fields. The strike is N.W.-S.E. with a dip of 80° towards west. It was impossible to ascertain whether amber is found all throughout this clay, but I rather doubt it. If we may judge from the extension of the old pits, which are chiefly on the top and the western slope of the hill, the amber is limited to the upper part of the blue clay. This view being correct, the amber would be found in a bed of highly inclined strata forming a broad band along the western side of the Nangotiemaw hill running in N.W.-S.E. direction. The continuation of the bed to the south will strike the supposed amber-mines at Lalaung.

The occurrence of amber.

It may be well to keep in mind that amber is nothing but a kind of resin which has been produced in exactly the same way as resin is produced by the trees now-a-days, only that the amber-producing trees—pine trees very probably—were extremely rich in resin, and that the process of production went on during tertiary times. The hardened resin accumulating in the amber-pine forest during the course of centuries was gradually washed away by the rains, and being of low specific gravity, easily floated down in the rivers to the sea, which then covered the whole of Upper Burma, where it was again deposited here and there. The amber deposits were covered with clay, the deposit of the sea, and this process may have been going on for a long period till the amber-bearing strata, as they present themselves in their present thickness of not less than 600 feet, had been formed.

It is therefore easily understood that the amber will be found in isolated pockets of smaller or greater extension and thickness, but once one of these pockets is exhausted the miner will have to look for another one, which may not be indicated by superficial signs. The native style of extracting the amber, to which I shall refer presently, must therefore be a highly speculative undertaking, as it merely depends on luck whether the workmen will strike an amber-bearing pocket or not.

The amber: its colour and value.

The amber is found in lumps of various sizes up to the size of a man's head; these are either rounded or more frequently flattened, having exactly the same shape as the pebbles on a beach, thus proving that they have undergone a considerable amount of wear and tear before they were deposited.

The colour of the amber varies from light yellow to dark brown, in all shades and various degrees of transparency, the most common colour being a dark reddish-brown, which may very well be compared with the colour of dark Madeira wine. Specimens of this kind are nearly always flawed, and contain streaks of minute fragments of wood. Transparent pieces are of a more reddish colour. The colour most valued by the natives is honey-yellow; larger pieces of this kind are rare. The milky-white, cloudy coloured variety, such as is at present particularly appreciated in Europe, does not occur in the Burma amber.

The Burmese amber is further more distinguished by one peculiarity which would lower its value in the European market; this is its fluorescence. This is the bluish tinge which appears when looked at under a certain angle, which is sometimes so strong that fine yellow pieces appear of an ugly greenish colour.

Mining for amber.

The amber is extracted in the most primitive fashion. No surface indications reveal the presence of a pocket of amber; the selection of a spot where mining operations are going to be started is perfectly accidental. Having selected a spot, a man digs a square hole of about 1½ feet by 2 feet by means of a rude tool, which resembles the Burmese taywin, that is to say, a short chisel-shaped iron affixed to a heavy wooden club-shaped handle. With this instrument the soft clay is loosened, and by means of a rough wooden shovel thrown into a bamboo basket, (both made on the spot) and hauled up by means of a long bamboo. In this way the miner digs himself gradually into the clay, constructing a chimney-like pit which just affords room enough for one man to work in. If an amber-bearing pocket is reached, which may be found at any depth, it is worked, and if of some extension, other pits are sunk around the original one until all the amber is extracted by working from one pit to the adjoining ones. As it happens frequently enough, no amber is found; then the pit is abandoned and another spot selected. It is perfectly clear that under this system of extraction the output solely depends on luck; one man may find a large quantity, while another works for weeks without getting more than a few pieces.

My experiments.

I was of course obliged to accept the native method, but all I can say is that I was extremely unsuccessful. Although I sunk about six shafts, which I worked with sometimes nine coolies at a time for nearly a fortnight, the whole output consisted of a few small pieces of disintegrated amber worth nothing. This may not be very encouraging, but in my opinion it is absolutely no sure test as to the value of the amber-mines; experiments to this effect must be carried out on a larger and more systematic scale and over a longer period.

Value of the mines.

Although I have no doubt that amber is found in large quantity either at Lalaung or elsewhere, it may safely be said that it will never form an article of export to Europe unless the fashion changes. The two qualities which are against it finding a market at home are, first, its colour; second, is fluorescence.

As regards the colour, only the milky white clouded pieces of amber command at present a considerable value in the European market; all the other colours, yellow and red, in their various degrees of transparency, are of inferior value, and would hardly be appreciated in Europe. Burmese amber would therefore range in the second place as long as the fashion does not change, and it is still more lessened

in its intrinsic value by the fluorescence which is never found in European amber. Only amber from Sicily shows the same peculiarity, and although found in some quantity, it is for this very reason practically unsaleable.

There is another reason why the fluorescence will be fatal to the Burmese amber. Up to only a very recent date the firm of Messrs. Hantien and Beeker in Königsberg, who are owning the monopoly of the Prussian amber-mines, which are the chief amber-producers, had every year an enormous quantity of refuse amber which could hardly be disposed of; the only way of utilising it being the manufacture of varnish, and as there is only a limited demand for such varnish, large quantities of the refuse were every year stored away. Some years ago the problem of smelting the amber was solved; the process consisting in softening the amber by steam under high pressure and then compressing the mass by hydraulic pressure. The amber thus produced resembled in colour the yellow or brown variety, its only difference from the natural pieces being its fluorescence. The firm, stopped the manufacture of this artificial amber because large pieces of it could be produced at such a low cost price that if thrown on the market it would have soon cut out the inferior qualities of natural amber altogether. The firm, rather than be its own competitor, stopped the manufacture of smelting the refuse altogether, and the storage of the latter is still going on. There is, however, no doubt that the very moment the Burmese amber, which in its physcal qualities is similar to the amber produced by smelting the refuse of European amber, would appear on the market as a serious competitor to European amber, the firm would at once take up the manufacture of artificial amber.

It may therefore be foretold with every certainty that if any company which might in the future exploit the amber-mines were not satisfied with supplying the local and China market only, but were to begin to export to Europe, it would find great difficulty in competing against German production; and it may even be doubted whether it would succeed in doing so, owing to the undoubtedly inferior quality of the Burmese amber. But whether the local demand, which may be estimated at about 2,000 viss per year at the outside, will be sufficient to pay a European company remains still to be seen.[1]

In conclusion, I would recommend that experiments on a larger scale should be carried out either at Lalaung or elsewhere with a view to ascertain whether there exists a sufficient quantity of amber to pay a more systematic mode of working.

Note on the Mogaung coal-field.

The so-called Mogaung coal-field might be more properly called Saungka coal-field, the outcrops of the seams being situated along the bank of a small stream of this name. The Saungka chaung is a feeder of the Mogaung stream, which it joins about 16 miles above Mogaung, running down from the hills on the right bank of the river. The coal seams are said to be found about 5 miles to the west of the banks of the Mogaung river. Although I did not visit the locality itself, I may venture a few remarks as to its probable value because I examined the country on both sides of the hills which contain the coal. There is no doubt that the coal is of tertiary age; the hills to the east consist, however, of metamorphic rocks, while those to the west consist of

[1] Dr. Noetling lays perhaps too much stress on the unfavourable appreciation which Burma amber may obtain in the European market. Its great area of sale is in the East, where it will probably hold its own against the European product.—*Ed.*

crystalline limestone, which probably sweeps round the northern side of the tertiary sandstones. To the south the latter are covered up by the alluvial plains of Mogaung. We can therefore safely say whatever may be the thickness of the seams, their extension is very limited, and it is further highly probable that the strata are very much disturbed.

Preliminary report on the Jade-mines. Situation of mines.

Two different groups of mines may be distinguished, which we may call the pit and quarry mines, respectively. The pit mines are situated along the bank of the Uru river, beginning at about Sankha village and extending for a distance of about 40 miles further down. The quarry mines near Tammaw village are situated about 8 miles to the west of Sankha village on the top of a plateau rising to about 1,600 feet above the level of the Uru river.

Geology.

Although it is quite probable the mineral which is commonly called jade and which forms the object of an extensive industry in the Mogaung sub-division is different from the jade proper, I may be allowed to use the old name till chemical and microscopical analysis will have revealed the true nature of this mineral. The Tammaw mines afford the best opportunity for the study of the geological condition under which the jade is found. It here forms a vein of considerable thickness in an igneous rock of blackish green colour. The jade is a purely white crypto-crystalline mineral much resembling the finest marble, containing here and there green specks of various sizes, which form the jade proper. The jade vein is separated from the black rock by a band of a soft and highly decomposed argillaceous mineral. The strike of the vein is approximately north to south, and the dip at about an angle of 20°, varying considerably towards east.

It is difficult to determine the age of these igneous rocks. Before Sankha is reached a similar rock may be seen breaking through tertiary sandstones, but unfortunately the relations of the Tammaw trap to the surrounding strata cannot be observed owing to the denseness of the jungle.

The jade extracted from the pit-mines is found in the shape of boulders, which are undoubtedly derived from localities hitherto unknown, in the neighbourhood of the Uru river. It is probable that this kind of jade, which has undergone a considerable amount of wearings much harder, and therefore of better quality, than the jade extracted from the quarry mines, which has hitherto only laid open the outcrop of the vein; but there is no doubt that once the mining operations have reached a greater depth, where the jade has no longer been subjected to the superficial disintegration, a material will be found which, if not better, will at least be equal to the jade extracted from the pit-mines.

Mining operations.

There are at least 500 men engaged every season in working the quarry-mines at Tammaw. The mining operations are carried on in the rudest fashion. No blasting powder being available, the rock is heated by large fires, and having again cooled down, is broken into pieces by means of enormous iron hammers.

The operation in the pit-mines are less difficult as the alluvial gravel in which the jade boulders are found does not require the tedious process of heating the rock. The miner simply digs a pit and selects the boulders from the stuff dug out of the pit; good pieces of jade are sometimes found in the laterite, which

forms beds of varying thickness along the Uru. These pieces have superficially undergone a certain discolouring in such a way that the original green or white is changed under the influence of the hydrated oxide of iron into a dark red colour. Specimens of this kind are generally known as "red jade."

Value of the mines.

There is no doubt that the jade-mines, especially the jade vein of Tammaw, forms a most valuable property; and there is further no doubt that, besides the Tammaw jade vein, others will be discovered sooner or later, as we know now that jade is intimately associated with a dark igneous rock (trap). As the country abounds in rocks of this kind, it may fairly be expected that a closer examination of these rocks, perhaps some extensive prospecting operation, will result in the discovery of other jade-mines.

Preliminary Report *on the* Iron-Ores *and* Iron-Industries *of the* Salem District, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Assistant Superintendent, Geological Survey of India.*

I.—Introduction.

The data and observations recorded in the following preliminary report on the iron resources and industries of Salem were gathered during a hurried visit to the district of less than three weeks, during which time I visited most of the places in which native iron-smelting is being carried on, and the principal localities in which the ores of iron occur. I have great pleasure in acknowledging the assistance which I have received during this short enquiry from Dr H. Warth, Officiating Superintendent of the Government Central Museum, Madras, who accompanied me over a large portion of the tour. To Mr. G. Stokes, Collector of the district, both Dr. Warth and myself are indebted for the courteous assistance of himself and his staff, and for many suggestions in discussing the possibilities of developing the immense iron resources of the district of which he has charge. In investigating the question of local fuel supply, Mr Brasier, District Forest Officer, has rendered invaluable help in continuing the enquiry which had received the attention of his predecessor, Mr. W. Carroll.

II.—Literature.

Besides the previous information obtained under the superintendence of the Collector, Mr. Stokes, I have been guided in the enquiry by the following publications containing references to the native smelting and the iron-ore of Salem :—

1814. HEYNE, B.: Tracts on India.

1836. BENZA, P. M.: "Notes on the Geology of the Country between Madras and Neilgherry hills *viâ* Bangalore and Salem."—*Madras Journal of Literature and Science*, Vol. IV, p. 1.

1842. NEWBOLD, LIEUTENANT, Mineral Resources of Southern India: No. 3: Chromate of Iron Mines, Salem District.—*Journ. Royal Asiatic Society*, Vol. VII, p. 167.

1855. BALFOUR, E.: Report on the Iron-ores, etc., of the Madras Presidency.

1864. KING, W., and FOOTE, R. B.: "On the Geological Structure of portions of the Districts of Trichinopoly, Salem, and South Arcot. *Mem., Geol. Surv., Ind.* Vol. IV, p. 223, *et seq.*

1881. BALL, V: Economic Geology of India (Manual, Vol. III), pp., 332, 335 and 348.

1883. LEFANU, H.: Manual of the Salem District.

III.—Mineralogical and Metallurgical characters of the Iron-Ores of the Salem District.

I give below a list of the ores of iron found in the Salem district, making special mention of the peculiarities in physical characters which these minerals display in this area, and their respective metallurgical values:

Magnetite.

(1) *Magnetite* is by far the most abundant of the iron-ores of the area. It occurs either in well-defined octahedral crystals, (which frequently display polar magnetism), imbedded in chlorite, schist, as in the neighbourhood of Rakkiyapatti, 11 miles south-west of Salem, and Ettumanikampatti, an *inam* village a mile further to the south.[1] These are picked-up in large quantities in the rivers after heavy rains, and the natives, knowing their magnetic properties, string them together as beads.

Magnetite occurs also, making, with quartz, a schist in which the crystals of magnetite are crushed out in the direction of foliation to a roughly almond-shape, the proximity of the tapering points giving a lacunar appearance to the rock. Crystals of about one-half to three-quarters of an inch in length, and of this shape, are common in the iron-beds of Kanjamalai and of many other places in the district. All gradations in size are found down to an almost aphanitic rock in which the constituent minerals are, to the naked eye, indistinguishable as individual crystals—a type common to all the groups of iron-beds. Bands of magnetite sometimes alternate with quartz, or bands of quartz and magnetite, rich in the latter mineral, are found alternating with bands of the former, frequently contorted into fantastic patterns and giving the appearances characteristic also of lavas which have cooled down after fluidal movement in a semi-viscous condition. The magnetite and quartz-schists, in common with all the crystalline metamorphic rocks, have, in fact, derived their peculiar flow-structure from actual moulding under the enormous pressures to which they have been subjected during great earth movements. I have noticed that these contorted pieces of magnetite-bearing rock are commonest near the ridges which form such a prominent and characteristic feature in the outlines of hills in which iron-beds dip at high angles. This, I presume, is not only due to the actual resistance to the disintegrating action of the sub-aerial agents, but

[1] The village of Ettumanikampatti is, curiously enough, named from the octahedra of magnetite,—*Ettu* "eight"; *mani* "bead," *patti* "village." (Tamil.)

also to the tendency to resist jointing and its consequent production of small fragments which form a more easily moved talus.

Friable ore used by native smelters.

The incipient expansion of the mass, accompanying the oxidation and hydration of the magnetite, has, in many places, been sufficient to produce a rock which crumbles under the slightest blow, or even between the fingers. These are the pieces exclusively used by the native smelters on account of their friable nature. They are invariably found in the talus at the foot of the hills, and probably are simply the more weathered representatives of the compact specimens occurring in the beds above. A further form in which magnetite occurs in this district is that of segregation from the main mass of the rock into cavities and pockets, as innumerable small crystals, which in large fragments frequenty exhibit a distinct polarity of magnetism. Magnetite occurs also, together with small crystalline fragments of quartz, felspar, hornblende, garnets and other minerals, as sand in the river-beds, being derived from the disintegration of the numerous crystalline rocks within the area. In the trappean rocks, in granites, and in the more basic gneisses, magnetite occurs in disseminated grains, but not in quantities sufficient for economic use. In almost any locality in the south of Salem district a magnet dipped into a bed of river-sand becomes coated with large quantities of magnetic grains.

Distinctive characters of magnetite.

Magnetite may invariably be distinguished by its hardness. It is always attracted by the magnet and frequently is itself magnetic with well-developed polarity in large specimens. The colour, both in large fragments and in powder, is black, with a well-defined metallic or sub-metallic lustre. These properties serve to distinguish it from the other iron-bearing minerals mentioned below. Besides being the most abundant, magnetite is the richest ore of iron, containing, when pure, 72·4 per cent. of pure iron, the re-

Metallurgical value of magnetite.

mainder being oxygen (Fe_3O_4). The ore which occurs in such abundance in the Salem district is thus the ore which has been used with such success in the Scandinavian iron-works. It was from this mineral, smelted with charcoal, that most of the famous Dannemora iron was produced. The Dannemora ore employed yielded on an average below 50 per cent. of the metal, varying between 25 and 60 per cent., whilst in the Salem district it is possible to obtain an almost inexhaustible supply of ore with an average of nearly 60 per cent. iron. This result is calculated from the average mineral composition stated by Messrs. King and Foote, and agrees with rough calculations of my own on crushed samples, as well as the estimate given by Balfour.[1] I have collected a large number of typical specimens which I hope to subject to analysis, the results of which will be embodied in the final report. I know of no published analyses of Salem ore giving the results of a search for such impurities as phosphorus, sulphur, and manganese; but from the reputation of articles of steel which have, in times past, been made from these ores by the well-known Arunachella Achari and others they must have been very free of at least both phosphorus and sulphur. Very small

Effect of phosphorus on steel.

quantities of *phosphorus* would be sufficient to render the steel distinctly brittle and "cold short"—as little as 0·1 per cent. is the maximum amount of phosphorus allowed in rail specifications, and in good qualities of mild steel it seldom exceeds ·016 to ·04 per cent. There is one

[1] Cyclopædia, 3rd edition, vol. ii, p. 372.

point worthy of consideration in connection with this question, namely the tendency for the phosphorus in pig-iron production to pass into a basic scouring slag rich in iron, whilst a good, grey slag—desirable in most places for economy of iron—produced in smelting, yields almost the whole of the phosphorus originally contained in the ore, fuels, and fluxes to the pig-iron. Fluxes are used in most places for the purpose of economising the iron, lime replacing the iron in the compound silicate of the slag, but in this district the ore itself is so inexpensive that manufacturers can afford to lose a highly ferriferous slag for the sake of cleansing from phosphorus. Whilst I have no doubt these facts may account in some measure for the purity of the iron and steel produced by the highly wasteful processes of the native smelters, who use no flux beyond that afforded by the ash of the charcoal employed as fuel, it is still probable that the Salem magnetite is comparatively free from this impurity, which is a source of so much trouble to steel manufacturers. Ward's analyses of the Dannemora magnetic iron-ore show it to be free of both phosphorus and sulphur.

Phosphorus in "scouring" slags.

Cause of purity of native steel.

The presence of minute quantities of ***sulphur*** in steel is even more powerful in its influence on the properties of the metal than that of phosphorus. As little as 0·05 per cent. of sulphur is sufficient to render steel sensibly "red short," or almost unworkable at a red heat—a character which has never been ascribed to the Salem steels. To these points I hope to give special attention after careful analysis of both the ore and of the pieces of iron and steel which have been purchased from the smelters still at work in different parts of the district.

Sulphur in steel.

Hæmatite is seldom found in large crystals in this district. In the hills to the south of Namagiripett I found small crystals of specular iron in larger masses of crypto-crystalline hæmatite, forming, with quartz, a schist bedded in conformity to the adjacent magnetite-bearing seams. Frequently we find both magnetite and hæmatite intermixed with quartz and, in some cases, I have noticed magnetite cores surrounded by hæmatite to varying degrees—producing, in fact, minute crystals of *martite* which is probably, in most cases, pseudomorphous after the magnetic oxide. Hæmatite contains 70 per cent. of iron, and is notably free from sulphur and phosphorus. This ore, when smelted, invariably gives a pig rich in silicon a property which has increased its demand for the production of steel by the Bessemer process; and, before the modification known as the basic process was introduced, only pig-irons rich in silicon were suitable for Bessemer conversion.

Hæmatite.

Martite.

Pig-iron from hæmatite for Bessemer conversion.

Hæmatite in this district is quite subordinate in importance to magnetite. From the latter mineral it can be distinguished, when crystallised, by its higher lustre, red streak, crystalline character, and the absence of all magnetic qualities. I have collected specimens of "soft" (that is, specimens in which the ore is in excess of the free silica) hæmatite from the northern flanks of the Kollimalais, in the south-eastern portion of the Salem taluq. It is, however, sometimes found with quartz predominating, and even passing into a jaspery condition in several parts of the district.

Under the action of atmospheric influences, hæmatite takes up water and passes into *turgite* and ultimately into *göthite* and *limonite*, or *brown hæmatite*. These may be carbonated to produce the various forms of *clay ironstone* and *chalybite*. Various stages of these processes are represented amongst the Salem iron-ores, especially the production of small quantities of yellow ochre by oxidation and hydration of the magnetite. This is the cause of the friable property of the ore, which is, as before stated, preferred by the natives. But as none of these ores, however, occur in sufficient quantities to be of any value for metallurgical purposes in comparison to the magnetite and hæmatite, they will receive no further attention.

Turgite, Gothite, Limonite.

Clay-ironstone.

Pyrite is conspicuously free from the rocks of this district. Finely disseminated grains occur scattered through some of the intrusive igneous rocks, but not in large quantities.

Pyrites.

I have found small crystals of titaniferous iron-ore in some of the eruptive rocks of Salem, but have never noticed it occurring in large quantities. Captain Campbell has recorded his discovery of titanium in a black ore used by the smelters of the Salem district, but he gives no particulars as to the quantity or nature of the mineral in which it exists.[1] Captain Newbold also states that iron-ore, slightly titaniferous, is found over the whole "hypogene area of Southern India."[2] I have not yet subjected the specimens collected to an analysis; but I hope to give this point due attention, as it is one of metallurgical importance. Although a very refractory mineral, titaniferous iron-ore has been used in the bloomery furnaces of the United States and Canada for the manufacture, by direct process, of wrought iron. The fine state of division in which the ore occurs as sand is favourable to its treatment by this process. At Mosie in Canada it is found profitable to wash sands containing only comparatively small quantities of the titaniferous ore before treatment in, as far as I could learn, the ordinary American Bloomery Furnace with simply a reduction in the slope of the twyers and of the pressure of the blast. The mineral is further used with a certain degree of success as lining material in some kinds of revolving puddling furnaces. The titanium itself seems to produce little or no effect on the iron manufactured. It has never been, I believe, found in white pig-iron and it seems never to pass into the malleable iron made from grey pigs which contain titanium. The action of titaniferous ore is not so much due to the presence in the product of titanium as to the conditions in the blast furnaces which are necessitated by the presence in the charge of minerals containing that metal. I do not consider (with our present knowledge of the uses to which *titanium* can be put in iron manufacture) the presence of the mineral in the Salem district to be of immediate value. Although such an authority as David Mushet was so firmly convinced of the value of titanium in steel as to take out thirteen patents for his invention, its value is still an unsettled question. One thing is certain, that the higher temperature required for the smelting of titaniferous iron-ores means a larger fuel demand which seems to be about the only bar to success in working the Salem iron resources. It is stated that the Swedish Taberg ore requires more than twice the amount of fuel to smelt ores containing titanic oxide than to reduce ordinary magnetic oxide. It seems, therefore, that the proximity of

Titanoferrite.

Metallurgical value of titanoferrite.

1 Campbell: *Calcutta Journ. Nat. Hist.*, Vol. II (1842), p. 280.

2 Newbold: *Journ. Roy. Asiatic Soc.*, Vol. VIII, p. 155, and Vol. IX, p. 40.

this accessory does not increase the value of the iron deposits to any material degree.

Pyrrhotite.

Pyrrhotite or magnetic pyrites, although of interest on account of its remarkable properties, is of no metallurgical value. It occurs in small quantities in some of the rocks of this district as minute hexagonal prisms.

Ferruginous clays and laterite.

Ferruginous clays, limonitic pellets, ferruginous sands and *laterite* frequently occur in different parts of the district; but these iron-bearing deposits, although in some places valuable as sources of the metal and for building and other purposes, are, in this district, developed to quite an insignificant degree beside the enormous deposits of richer iron oxide.

Chromite.

Chromite in many respects resembles magnetite, having like it a black colour and sub-metallic lustre. It crystallises in the same form and has about the same hardness, whilst its specific gravity does not differ from that of magnetite sufficiently to allow of such a means of discrimination between hand-specimens of the two minerals. It is also sometimes magnetic. The property which at once distinguishes it from the magnetic oxide of iron is the colour of its powder. Chromite gives a brown streak, whilst that of magnetite is black. In chemical composition it differs from magnetite in a replacement of the iron sesqui-oxide wholly or partially by the corresponding chromic oxide. Besides the value of this mineral for the production of the various chrome-salts used as pigments, its use as an introduction into steel and iron adds to its value on account of its proximity to the rich iron-ores of Salem. Ferro-chrome has a decidedly beneficial effect on steel, and only the expense of the ore, and the difficulties attending the smelting of such an easily oxidised metal as chromium, prevent its more extended use in steel manufacture. It is, however, coming into great favour specially in Sweden, where the ores of iron are, in many respects, similar to the Indian ores, both in properties and mode of occurrence. In Tasmania chromic ores containing sulphur have been considerably smelted, although the presence of sulphur necessitates the expensive remelting of the pig with ferromanganese. Whilst for rails its price will probably always prevent it superseding ordinary carbon-steels, the use of chromium-steel for the manufacture of armour-piercing projectiles seems to be decidedly on the increase, and the only substance which seems capable of replacing it to any extent will be a modified form of the remarkable manganese-steel recently made by Mr. R. A. Hadfield. For want of available literature I am unable at present to quote any data showing the enormous hardness, tenacity and great resistance to impact possessed by chromium-steel, but it may with safety be said that the attention which this alloy will in all possibility receive would make the presence of chromium in the Salem district a valuable accessory to the iron. In the sequel I shall show that the conditions which invariably accompany deposits of chromite are present not only on the chalk-hills in Salem, but are repeated in every respect at the foot of Kanjamalai itself, the hill so well known for its iron-beds from the interesting description by Messrs. King and Foote in the memoir already referred to.

Chrome-pigments.

Chromium in steels.

Chromium-steel projectiles.

Hadfield's manganese steel.

Possible occurrence of chromite in Kanjamalai.

Manganese ores.

Manganese ores.—The principal remaining substance of value in the manufacture of iron and steel is manganese. Although there are, as far as I know, no deposits of these ores in the Salem district, *braunite* is said to occur in the Kurnool district and near Tumkoor in Mysore. Notwithstanding the recent impetus given to the use of manganese in steels, I do not consider that these places—which are the nearest known manganese-bearing localities—are sufficiently near Salem to be worth considering in the question of the successful revival of the Salem iron-industry. They will be treated more fully in dealing with the respective localities in the final report. I can only call attention to this *possible* means of adding to the chances of development of the district at present under consideration.

IV.—Distribution and geological relations of the Ores.

Concerning this question I have very little to add, beyond the mineralogical notes already given, to the descriptions published, in 1864, by Dr. King and Mr. Foote in the memoir above quoted, and to the additional summary written by Mr. Foote for the District Manual (Volume I, pp. 97-102, and occasional references under the headings of the different talúqs in Volume II).

Additional remarks on the Kanjamalai iron-beds.

As to the celebrated iron-beds on Kanjamalai, I have been able to work out the exact points of junction of two of the beds with the adjacent rocks by working along the top of the westerly extension of the high ridge. In his description of Kanjamalai, given as an appendix to the memoir, Mr. Foote states his inability to decide on the thickness of the deposits owing to the manner in which the lines of junction of the beds are obscured by the debris rolled down from above (p. 382). A thickness of about 50 feet is estimated for each of the two lower beds. But, as stated, the exact thickness is of little importance when the quantity of ore is so enormously great. My actual measurements on the western ridge of two beds showed that even this estimation is rather understated. One bed measured nearly 50 feet, whilst the other was very little under 100 feet in thickness. The thicker of these beds is possibly the lowest (No. 1) of Mr. Foote, whilst the thinner seam below would, in that case, be unrepresented on the main mass of Kanjamalai. The reasons for this statement, although the results of a necessarily hasty examination, I will state presently. The iron-beds are described and mapped as concentrical ellipses; but had Mr. Foote the privilege of re-examining the ground he would probably make a slight modification of his map on the north-west side of the hill. Although the modification is of little concern as to the iron resources themselves, I hope to show that the disturbances on the north-west side have given rise to a recurrence of the conditions which prevail near the chromite-deposits of the Chalk Hills, and thus becomes of possible economic value, as well as of scientific interest.

Thickness of beds.

Geology of western extension of the Kanja ridge.

Crossing the road in the southerly direction near Sithaswaran Kovil, one mile east of the village of Kadiampatti, one meets first with talcose and chlorite-schists exposed in the river-bed, and giving the general east-north-east and west-south-west strike of foliation, with a high dip to the north-north-west. For a few yards further the rocks

are covered with soil and the next exposure is that of a coarsely crystalline hornblende felspar rock with large garnets. This rock follows the general direction of foliation, but unlike the talcose and chloritic schists referred to, its dip is towards the mountain, and of 55°. There is probably thus an anticline to the north with its axis parallel to the direction of foliation. This rock is succeeded by a narrow dyke of basic rock intruded in the direction of strike, and following this we have a parallel arrangement of other foliated rocks, some with garnets, some without, and one or two eruptive rocks, all following a general east-north-east direction until the base of the mountain is reached, when they disappear under the talus of broken fragments of rocks fallen from steep slope above. The rather broken and low ridge of these rocks forms the northern boundary of an irregular depression which is backed in the easterly direction by the main mass of Kanjamalai and on the southern side by heights rising to 650 and 950 feet above the plain and forming the continuation of the main ridge of the mountain. It is within this depression that the complications of the strata to which I have referred occur. In the westerly direction the rocks are found to have a strike of almost due north and south and dip at about 50° or 60° towards the mountain, that is, towards the east. This direction changes for a north-west and south-east strike on ascending the hill to the south, and on following the ridge to the east the strike curves round to the west-south-west and east-north-east direction with, in the main mass, a northerly dip as shown in the section given by Mr. Foote (*loc. cit.*, p. 380). By this means beds which formed the base of the main mass of the mountain are brought obliquely across the westerly ridge, and on the edge of the ridge are laid bare for examination. Of the two beds so exposed, the lower and thinner rests on a garnetiferous, foliated hornblende-felspar rock. Between the two beds there is a thin seam of hornblendic gneiss about 20 feet thick—an occurrence nowhere described in the memoir. I conclude, therefore, that the heavy debris obscuring the beds on the main hill-slopes concealed this thin bed of gneiss from the observation of the original observers, whilst if this large bed, which bends around to the north-west, is a continuation of their bed No. 1 from the southerly side, then I have missed, in my hasty climb, the thin indurated bed of talcose schist (*loc. cit.*, p. 380, fig. 9). This is very possible as the task of working up towards the summit was by no means facilitated by the rolling boulders and thick, thorny tangle of bushes. The two highest points on this westerly extension were, by aneroid readings, respectively 650 and 950 feet above the plain, and from the last point to the summit, and down over the northern slopes, my observations coincided precisely with the account given by Mr. Foote.

Anticline to north of Kanja.

Exposure of iron-beds on the western ridge due to change in direction of strike.

In the depression on the north-west corner there are ramifications of a great dyke of graphic granite running generally parallel to the foliation, but in places cutting across the gneiss. Further complications are brought about by the intrusion of black hypersthene-bearing and other pyroxenic rocks, which seem to have been intruded in order from the basic rocks to the acid granite. Towards the west quartz-veins bifurcate and ramify amongst the basic gneisses; but the most interesting feature is the occurrence of veins of *magnesite* traversing precisely

Intrusive basic and ultra-basic rocks on the north-west side.

Magnesite.

the same kind of decomposed and crumbling rock as we find in the sides of the chromite shafts on the northern magnesite area of the Chalk hills near Salem, It is associated also with compact, and sometimes fibrous serpentine or picrolite (baltimorite). As the occurrence of these minerals in Kanjamalai has not been recorded by Messrs. King and Foote, a description and a comparison of the essential geological features of this area and of the Chalk Hills will explain my reasons for considering the occurrence of chromite in the Kanjamalai by no means an improbable discovery.

Fibrous serpentine.

Lieutenant Newbold, in one of his series of communications on the mineral resources of Southern India to the Royal Asiatic Society, described the chromite-mines of the Chalk Hills. This paper seems to have been overlooked by Messrs. King and Foote, who, consequently, could say little as to the mode of occurrence of the chromite. The mines were also inaccessible at the time of their visit, but since that time the rubbish, which has fallen in from the sides of the shaft, has afforded a convenient soil for the growth of a tree (*Ailanthus excelsus* or *Pi-maram*) in each of two of the shafts. These are now grown to the mouth of the shaft and stand in striking contrast beside the stunted shrubby acacias of the surrounding area. By one of these trees I managed to climb down to the bottom of the shaft, now only 35 feet deep, and my observations, on the walls and of the fragments at the bottom, confirm Newbold's description of the mode of occurrence of the chromite.[1] At the time of Lieutenant Newbold's visit, the shafts were respectively 59 and 63 feet deep, but since that time a third shaft has been made and a few smaller excavations, apparently of a trial nature, are still to be seen about the immediate neighbourhood. Water was found in quantity at 59 feet, but the workers possessed no better means of removing it than by the use of ropes and buckets. The ore follows the direction of the magnesite-veins, but is found generally between the magnesite and the main mass of crumbling rock. One large mass, weighing 2 tons, was also found before Newbold's visit At present the only chromite visible is in small quantities lying in the manner described above. I have collected specimens of the ore for further examination. An analysis by Mr. E. Solly of a piece collected by Lieutenant Newbold yielded 49 per cent. of chromic oxide and resembled the material brought from America and from the Shetlands.

Chromite mines of the Chalk hills.

Observations in the chromite-mines.

Mode of ocurrence of chromite.

Judging from analogy of other occurrences of chromite and its constant associate, serpentine, the formation in the Chalk Hills is not improbably the remains of a great ultra-basic intrusion. I have found dykes of undoubtedly basic and ultra-basic rocks in the neighbourhood, and serpentine has, in many instances, since the date of the publication of the Survey memoir, been proved to be the hydrated product of the highly magnesian constituents of ultra-basic and olivine-bearing, igneous rocks. The rock known as *dunite* from New Zealand contains chromite imbedded in olivine, which has, as yet, only suffered the incipient hydration to which olivine is undoubtedly susceptible. The same dykes of

Paragenesis of chromite.

Dunite.

[1] *Journ. Roy. As. Soc.*, Vol. VII (1843), pp. 167-71.

ultra-basic rock, the same decomposed material, bearing magnesite in similar veins, and serpentine both in its fibrous and in its compact form, are all found at the north-west base of Kanjamalai. Whilst it is to be admitted that chromite is most irregular in its distribution amongst these rocks, there remains the suggestive fact that these conditions are precisely those under which the mineral is invariably found; and I think it is at least worth more than the search of the few hours which were at my disposal. Nothing but a careful working out of the petrological relationships of these rocks will result in successful prospecting for valuable minerals.[1]

Same phenomena in Kanjamalai.

Search for chromite suggested.

Messrs. King and Foote are unconsciously unfair in their criticism of Dr. Benza's observations in the Chalk hills. Dr. Benza did not, as they imagined, overlook the serpentine, either in its ordinary or in its fibrous form. Dr. Benza could not be expected to call the mineral by the name of *baltimorite* for the very obvious reason that this name was not coined until seven years after the publication of Benza's interesting paper. The author of the term *baltimorite* was himself quite unconscious of the affinities which the mineral possessed for serpentine and proposed the word, as he did many others, in the indiscriminate manner characteristic of the times when mineralogy was less of a science than postage-stamp lore! The word *picrolite* was used for this form of serpentine as long ago as 1808, and has the preference both in age and scientific accuracy. Baltimorite can offer no apology for its existence. I have referred to this point because it explains the terms used by previous writers on he geology of Salem—Heyne, Benza, and Newbold. The last two authors both spoke of the existence of asbestos and nephrite,[2] whilst Heyne referred to a "semi-pellucid greenstone" which is about the hardness of serpentine and looks not unlike the famous image stone of China.[3] The confusion which existed at that time between the complex minerals nephrite, jadeite, bowenite, and agalmatolite (which is used at the present time for ornamental carvings in China and elsewhere), and the varieties of serpentine, explains the use by Benza and Newbold of "nephrite," whilst the interesting circumstances attending the examination of the original specimen of baltimorite explains the term "asbestos"—the name under which it passed before coming into Professor T. Thomson's hands. Curiously enough it was labelled "asbestos with chrome."[4]

Benza's discovery of serpentine in the Chalk hills.

Picrolite and baltimorite.

"Nephrite" and "asbestos" of Benza and Newbold correspond to "serpentine," and "picrolite" (baltimorite).

With regard to the place mentioned by Benza as a further locality for magnesite, namely Yedichicolum, close to the Cauvery, near Trichinopoly, Messrs. King and Foote have expressed some doubt. I hope to investigate this matter on taking up the Trichinopoly district; but, in the meanwhile, I might mention that Newbold

[1] Since writing the above in camp, I have examined, in the laboratory, specimens collected on Kanjamalai and on the Chalk hills, and find that in each case the magnesite is formed, as suggested, by the decomposition of olivine-rocks closely related to dunite.—*T. H. H.*

[2] Benza: *Madras Journ. Lit. Sci.*, Vol. IV (1836), p. 23.—Newbold: *Journ. Roy. As. Soc.*, Vol. VII (1843), p. 168.

[3] *Cf.* King and Foote: *Op. cit.*, p. 241.

[4] Thomson: *Phil. Mag.*, Vol. XXII (1843), p. 191.

PARIAHS SMELTING WROUGHT IRON, SALEM DISTRICT

also refers to the same place as containing, not only magnesite, but chromite, and he further refers to "Hoonsoor, Mysore and to a site near Comarpollium, 10 or 12 miles south-west from Sankerydroog, in the Salem district."[1] Of other occurrences of chromite in India the same association with serpentine has been recorded. Amongst these I may refer to samples found by Mr. Mallet weathered out of the serpentinous rock of Spiti[2] and in one or two places in the Andaman Islands.[3]

I have already referred to the increasing value of this mineral.

Remaining groups of iron-ore beds described by King and Foote.

With regard to the remaining groups of iron-ore beds described in this memoir, my observations confirm the descriptions of them in every particular and the time would not allow of extending the details. These groups will be referred to in discussing the fuel supply.

V.—Native smelting processes.

At the present time both wrought iron and steel are being manufactured by pariahs in the Salem district; but I nowhere found steel (*wootz*) being *made in crucibles*, as, according to previous writers, was the case when the industry was in a more flourishing condition. Wootz, however, is still being made in the adjoining district of Trichinopoly.

Manufacture of wrought iron.

The process of manufacturing the wrought iron is simply a very primitive and imperfect form of the Catalan and Bloomery process at present employed in Europe and America. The furnaces are smaller and much more imperfect in every way than the furnaces which I saw in the Ernad talúq of the Malabar district. The mode of working the bellows is also different from that of the western workers, who are in the employ of Mahommedan moplahs. The process of smelting one bloom occupies about two or three hours, the resulting iron weighing about 18 lbs., whilst the Malabar workers occupy as many days for the production of a bloom of iron weighing about 5 cwt. In Malabar also the charcoal and iron are all weighed and the products sold by weight in four grades, whilst in Salem the workers do everything by guess, with the result that there is an enormous waste of either ore or fuel; and the sale of the bloom is a bargain at sight without regard to weight. The pariah workers seem to possess little sense of either time or weight, and professed great amusement at my suggesting some simple improvements on the method which they and their ancestors had practised all their lives! (Plate I.)

Comparison with Malabar workers.

Mining the ore.

The processes of mining (or "grubbing," for the diggings are never more than 3 feet deep) the ore are even more wasteful than the smelting. Only the well-disintegrated and rotten pieces of quartz-magnetite schist are used. All the pieces too hard for easy crushing, even nearly pure magnetite, are rejected, and, consequently, the material contains not only large quantities of quartz-grains, which have to be removed in preparing the ore

[1] *Journ. Roy. As. Soc.*, Vol. VII (1843), p. 169.

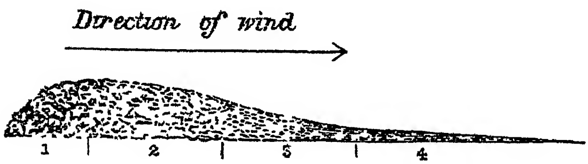
[2] *Mem. Geol. Surv. Ind.*, Vol. V, p. 167.

[3] *Rec. Geol. Surv. Ind.*, Vol. XVI, p. 204; Vol. XVII, pp. 83 and 84. The serpentine has been mapped by Mr. R. D. Oldham (*Rec. Geol. Surv. Ind.*, Vol. XVII, pp. 135, 145 and plate).

for smelting, but, in addition, a considerable amount of limonitic dust which is also carried away in the subsequent process of cleaning the magnetite.

Dressing the ore.

In dressing the ore the large fragments are crushed with a flat hammer, about 3 inches square, one man using the hammer, whilst the other is continuously heaping the larger fragments into the central part of the pile. After sufficient material has been accumulated, the crushed rock is winnowed by pouring out of a basket in a strong wind. The heap which so forms is divided into four portions, as shown in the accompanying sketch-section. No. 1, consisting of large pieces, is to be re-crushed. No. 2 is



cleaned of its quartz by sifting in a shallow basket similar to that which is used for separating rice from the husk and for sifting coffee to remove the imperfect berries. Towards the end of the concentrating process the fragments which find their way to the lip of the basket are compound grains of quartz and magnetite; these are dropped back upon the pile for re-crushing, instead of being thrown away with the quartz waste. When the magnetite is well concentrated, it is taken in this state to the furnace, but has still to the re-crushed and sifted before it is fit for smelting. This last process, however, is carried on near the furnace. No. 3 of the winnowed pile is composed of *fine* grains of quartz and magnetite, and the concentration is brought about by washing in the river. The workers are, from practice, evidently aware of the fact that reducing the specific gravity of each mineral by 1 gives the magnetite a greater proportional weight over the quartz, for that of course is the principle on which they adopt washing in preference to sifting for the finer particles. Section No. 4, consisting almost wholly of limonite-dust, is rejected as useless.

Washing the ore.

Steel manufacture by de-carburisation.

The process of smelting for wrought iron has been so well described by previous writers that I will add no more in the present preliminary report. But the manufacture of steel is so altogether distinct in principle and practice from any native process which I have seen described that I will give an account of the operation which I examined in one or two places. In 1840 David Mushet published an account of his elaborate experiments on the samples of wootz, submitted to him[1]; and, in referring to Mr. Heath's paper to the Royal Asiatic Society, he was puzzled at the two kinds of steel which were brought to England from India. The steel was sometimes brought in the form of conical ingots and sometimes in flat, round cakes. The former kind was evidently the ordinary wootz, as still made in crucibles in Trichinopoly. The latter kind is now made in the Salem district, but by a process quite different from that of the crucible wootz. Heath, in his paper,

[1] Papers on Iron and Steel, 1840, p 650.

Photo by T H Holland Lith & Prtd Geol Surv Office

PARIAHS MAKING STEEL, SALEM DISTRICT

seems to have overlooked the latter process, and, as far as I am aware, it has been generally left out of desciiptions of the native smelters. The conical ingots of wootz are made by *the carburisation of wrougnt iron in crucibles,* the principle which was not applied in England until 1800, and which governed the later patent of Mackintosh, and since modified to the modern cementation process for the conversion of bar-iron into " "blister steel," and in "case hardening." The flat cakes of steel now being made in the Salem district are, on the contrary, produced by the partial removal by oxidation of the carbon in cast iron, as in the open-hearth finery of Styria and Carinthia, and in the ordinary puddling of pig-iron. The former material is made by *carburisation* and the latter by *de-carburisation.* The following is the process as now carried on:—

Steel-making process in Salem.

In the manufacture of wrought iron, certain easily fusible beads of iron are produced and melt off as shot. These are in reality highly carburised particles, or cast iron, and it is from these that the steel is made. The shot are first pounded in a stone mortar with a wooden pole guarded with an iron ring—the *olakai,* used for pounding rice. By this process the small particles of slag adhering to the shot are removed, and the cast iron receives an imperfect polish. The powdered slag-material is separated by sifting in the ordinary manner in a *moram,* or shallow basket. A hole is dug in the ground about one foot deep and about one foot in diameter. At one side a semi-circular groove is excavated from the surface to the bottom of the pit. A large cake of soft clay serves to divide this small excavation from the other part of the pit, and the smaller chamber serves as the finery in which the steel is made. The bottom of this is first covered with a layer of dirty quartz obtained from sifting the crushed ore, as described in the process of dressing the magnetite for the furnace. There are generally pieces of magnetite adhering to this quartz, which fact accounts for the "orey particles" in the cakes of steel produced, and which so puzzled Mushet to explain, and from which he concluded the steel must have been produced direct from the ore. On this hearth of quartz an ignited coal is placed and the small chamber filled with charcoal. A tuyere, previously built in with the clay partition, points downwards at an angle of about 45° and receives the nozzles of two goat-skin bellows, by which a continuous blast is maintained. The shot are first wetted and thrown upon the charcoal, the amount used being governed by pure guess-work as in the wrought-iron smelting. The blast is continued for about half an hour, when the process of decarburisation is complete, and the tuyere and clay-partition broken down for the removal of the steel-cake, which is first slightly cooled by a dash of water and then hammered to remove the casing of slag which has formed around it. I have secured several cakes of this material, and hope to subject them, as well as the cast-iron shot employed, to experimental tests in the laboratory. The workers are quite aware of the fact that if they continued the process too long, the resulting product would be of no more use than ordinary wrought iron, although, of course, they do not know that the removal of the carbon, which gives the steely properties to iron, is the result of continued oxidation. The cakes of steel which result are sold for 4 or 5 annas each. (See Plate II.)

It seems curious that these pariahs should adopt this interesting process for the manufacture of steel, whilst the typical wootz is made in such an entirely different manner. They professed ignorance of any method other than that which

they now employ, and they have been carrying on this method as long as any of them could remember. Regarding the conservatism of these people as a constant, one might suspect their industry to be of independent origin and they of a different caste from the wootz-makers still at work in South Trichinopoly. It will be interesting to cross-examine the wootz-manufacturers on this point.[1]

Localities in which smelting is carried on.

In the Salem district smelting of iron is confined to the Salem. Trichengode and Attúr talúqs, the work which was formerly carried on in the talúqs of Namakal, Úttankarai, and Hosur having been given up as profitless. At most of the places where smelting has been, or is being, carried on, I noticed large heaps of ashes and slag, sometimes 10, 15 and 20 feet high, with, in one or two cases, trees of one foot or more in diameter growing on the heaps.

During our visit Dr. Warth and myself found and examined smelters and their furnaces in the following places :—

(1) SALEM TALÚQ.

Námagiripett.—Several slag-heaps and groups of furnaces for the manufacture of both iron and steel. Ore is obtained from one of the outlying low hills of the Kollimalais, about 3 miles south-east of the village. Fuel was obtained from Kadiampatti and Mullu-kurichi forests, about 10 to 12 miles from the furnaces.

Perumapalayam, about 1½ miles north-east of Karipatti. A large slag-heap and the remains of two or three furnaces. Smelting carried on last a year ago, when ore and fuel were obtained from Godumalai, ½ mile from the village. When the work was in a more flourishing condition, ten years ago, fuel was also obtained from Thaimalai, a distance of 2½ miles.

Tirúmanúr, 7 miles south of Karipatti. Ore obtained from 2½ miles north of the village. Charcoal from wood in the forests around the place. One furnace working ; the remains of others standing.

From enquiries, I heard there were smelters at work in the following additional places in this talúq :—

Konganapuram, 7 or 8 miles west of Kanjamalai, which is the source of the ore.

Vanavási and *Soragai*, both places near *Nangavalli*, 21 miles north-north-west from Salem *viâ* Taramangalam.

Twenty or thirty workers are said to be still smelting in these villages.

(2) ATTÚR TALÚQ.

Attúr.—A slag-heap with remains of six furnaces for wrought iron. One for iron and one for steel still at work owned by one Sanyasi Pariah in Kattyakara Street. Ore is obtained from Múragathúmalai, 4 miles west-south-west of Attúr, and fuel from a distance of 6 miles.

Thondaroyapuram or *Meykapalliur*, 4 miles west of Attúr. Three furnaces worked for the last time in January 1892. Ore from Muragathúmalai, 1 mile to the south-east. Fuel from same range of hills.

[1] Since this was written I have examined the makers of crucible-wootz in South Trichinopoly and find they are of the Karuman caste. A description of these workers is given in a separate report.—*T. H. H.*

Mathurútú, 3 miles west of Mallikarai. On account of the present scarcity work stopped for a month. One smelter was about to make a bloom at the time of my arrival, and, on its completion, I bought it for 5 annas. He said the ore was obtained from the Godumalai and fuel from Poonamalai, 1½ miles from the village.

Keerapatti, 2 miles south of Mallikari. Smelters worked up to February 3rd, 1892, and find it, at this time, more payable to do cooly work, principally in cutting firewood. There were five furnaces on a slag-heap 2 feet high. The working has been carried on in the place little over two years, the smelters having come from Mathurútú, Nahempatti, and Meykapalliur. Charcoal obtained from Valakumba, 2½ miles east. Ore from Nahempatti, 4 miles south.

Nahempatti, on the road to Tammampatti. Some ore may be obtained close to the village, and more 1 mile to the east in the Parmamalai. Charcoal from Taletalai kaidú, a distance of 4 miles. Slag-heap, 10 feet high. Banded magnetite-quartz schist is used here for road-metal.

Tammampatti.—Five good furnaces, but none of them worked fornearly six months. Slag-heap 15 feet high. Ore from Parmamalai, 2½ miles north-east of furnaces, the ore which occurs within a mile to the north being neglected. Fuel was obtained from Válákumba forest, 2 miles west.

Chendarapatti, 2 miles east of Tammampatti. One furnace at work. Ore from 5 miles east, Kudúmalai. Slag-heap 10 feet high, with remains of four other furnaces.

Tukkiampalayam, 2 miles north of Valaipádi. Three good furnaces and remains of eight others. The only variation I have ever found in the shape of the furnaces was the use of a square and more strongly built base at this place. Ore brought from the Godumalai in the Salem talúq. According to the statement of the pariahs charcoal from 10 miles.

Smelting is not now carried on at *Nárakanar*, 6 miles north-west of Tammampatti and *Kadambúr*, 7 miles south of Attúr, localities in which a thriving industry was formerly carried on.

(3) TRICHENGODE TALUQ.

In the Sankaridrug division, ore from Kanjamalai is still smelted by pariahs in the following villages:—Valayasettipalayam, Konganapuram, Iruqaluruttapalayam, Padavedu and Ayigoundenpalayam. In six other villages, where the industry formerly flourished, it has now died out.

The workers unanimously say that the increased price of fuel has been the cause of reducing the industry, and many of the workers have lately stopped on account of the present scarcity and consequent small demand for the iron for implements. Although this cessation of work may be only temporary, it is possible that this might in many of the villages be "the last straw" on a dying industry.

VI.—Fuel Supply.

For the production of charcoal the favourite wood seems to be the *Wúnjai* (*Albizzia amara*)—the *Oosulay* of Malabar. The timber is extremely hard and

mottled with concentric, alternating light and dark bands. It is said to be extensively used for fuel on the locomotives in Salem. I have secured specimens of the wood and its charcoal for the purpose of determining its calorific power and other properties in the laboratory, and for the estimation of its ash. I have also secured specimens of three other, but less favourite, woods used by the pariahs:—

Sembalichán (*Erythroxylon* (*Sethia*) *indica*), a dark-brown wood.
Nekani (*Canthium didymum*), a small tree with hard, grey wood.
Woodavai (? *Adave* of Manual) (*Grewia rothia*).

Details concerning the supply of fuel available from these forests have been submitted to the Madras Government by the late Acting Forest Officer, Mr. W. Carroll. This information has been conveniently arranged with reference to the main groups of iron-bearing beds, following the classification of Messrs. King and Foote, and divided between the talúqs of Salem, Attúr, Námakal, and Uttankarai.

In the *Salem talúq*, from the 47,800 acres of available forest, Mr. Carroll estimates from a clean felling 11,472 tons of timber, which would produce 2,699·3 tons of charcoal—sufficient probably to manufacture 830 tons of iron. A partial clearing of the forest would allow of little less than half this yield.

In the *Attúr talúq*, the yield of timber is estimated in the present state of the jungles to be 833 tons per annum—a quantity sufficient only for the manufacture of 58 tons of iron.

In the reserved portions of *Námakal talúq* a partial clearing would give 2,816 tons of timber—sufficient fuel, when converted into charcoal, for smelting 220 tons of iron. To this must be added a probable yield of 2,550 tons from the unreserved portions, giving 196½ tons of iron.

Uttankarai talúq has an available forest, reserved and unreserved, of 31,946 acres; this amount is within a radius of 5 or 6 miles from the Thirthamalai magnetic iron-beds. The reserved portions would, with clean felling, yield 7,000 to 8,000 tons of timber, and with partial felling, 4,000 tons—equivalent to about 1,000 tons of charcoal. The unreserved portions of 4,100 acres giving a yield of 2 tons per acre would with a 20-years' rotation give only 410 tons of charcoal. Taking these two quantities together we have sufficient charcoal in Uttankarai to manufacture 433 tons of iron. The jungles lying east-north-east and south of Thirthamala reserve would on the above rotation yield sufficient charcoal for an additional 192·3 tons of iron.

We thus have in the vicinity of the iron-bearing beds sufficient timber for the following yield of iron per annum:—

		Timber.	Iron.
Salem	*talúq*	5,736 tons.	400 tons.
Attúr	„	833 „	58 „
Námakal	„	5,366 „	416 „
Uttankarai	„	8,140 „	625 „
	TOTAL	20,075	1,499

Statement showing the number and names of the Magnetic Iron-ore beds within the Salem talúq, the Forests nearest to them, and the probable quantity of Fuel to be had from them, etc.

Name of group.	Names of forests, reserved and unreserved, nearest to the group.	REMARKS.
1. Kanjamalai.	1. Bodamalai 2. Mallúr 3. Nagaramalai 4. Jallathu 5 Suriamalai 6. Vanavasi 7. Pakkanad	The first four jungles lie within the Salem talúq and the other three in that of Trichengode; the nearest are Nos. 1 and 2, "Bodamalai and Mallúr," which are from 10 to 12 miles away as the crow flies and from 20 to 22 by the cart road. As the cost of manufacturing iron was found to be so very costly in 1861 (*vide* District Manual, page 99), and had to be abandoned, much more so now, as more will have to be paid for fuel, labour for cutting same, and converting into coal, etc., that I don't think it would be worth while for any company to start the industry again. There are of course other scrub jungles nearer, mostly within mitta limits, but the fuel to be had will very soon be exhausted, as the tract contains chiefly scrub growth.
2. Godamalai and a small portion of 3 Singipatti.	1. Jallathu . 12,000 acres 2. Godamalai 5,600 " 3. Vellampatti 5,500 " 4. Kuruchi . 2,300 " 5. Illapadi . 3,600 " 6. Kudma-duvu . 4,300 " 7. Pungama-duvu . 2,500 " 8. Kombakal 8,000 " 9. Manjava-digha, one-half . 4,000 " TOTAL . 47,800 acres	The iron beds of this group (*vide* District Manual, page 100) extend from a point 7 miles east by north of Salem along the Godamalai ridge, then past Belur north-eastward up the Nayamalai, and thence along the eastern slopes of the Tenandimalai for many miles; the last-named hill lies in the Uttankarai talúq. The forests within 5 miles of this group on either side are noted in column 2. Their aggregate extent will be about 47,800 acres, or a little over 74 square miles. The first three noted contain poor growth, while the others may be classed as middling to very good. The average outturn per acre, if a clean felling is made, can be set down at 6 tons, and at 3, if partially cleared, that is, if all the trees suitable for timber are left—taking the yield at 6 tons an acre, and allowing for a rotation of 25 years, the nine jungles named will yield $\frac{47,800}{25} \times 6 = 11,472$ tons as from 4 to $4\frac{1}{2}$ tons (average $4\frac{1}{4}$) of fuel are required for giving 1 of coal, the outturn in coal will be $\frac{11,472}{4\frac{1}{4}} = 2,699{\cdot}3$ tons, or sufficient to manufacture a little over 830 tons of iron, if $3\frac{1}{4}$ tons of coal are required before one of iron (*vide* page 99 of the District Manual). If, however, it should be decided to make a partial clearing only, then the outturn in iron will be about 400 tons only.

Statement showing the Jungles bordering the Iron beds of Singipatti or Singipuram and of Kollimalai in the Attúr talúq.

Name of group.	Names of Jungles.	Extent.	REMARKS.
1. Singipatti or Singipuram.	1. Godamalai 2. Jallathu 3. Manmer	Acres. 5,600 12,000 4,000	This group (quoting from the District Manual, page 100) lies 4 miles south of the Godamalai and extends some 10 miles in a generally east-north-east to west-south-west direction. The forests bordering same and within 5 miles on either side are noted in column

Statement showing the Jungles bordering the Iron beds of Singipatti, etc.—contd.

Name of group.	Names of Jungles.	Extent.	REMARKS.
1. Singipatti or Singipuram—*contd.*			2. In addition there are several patches of unreserved land containing very poor growth, so that the fuel for the working of this group will have to be drawn from the reserves noted. The first two have already been entered in the statement for Salem talúq. The other "Manmer" contains very little growth and will not yield more than 1 ton of fuel per acre. The slopes of the Periakalroyan are a little farther off, but I don't think it would pay any company to get their fuel or charcoal from these, so that the Godamalai and Jallathu reserves are the only two from which fuel to a limited extent can be drawn.
2. Oilpatti.	*Nil.*	*Nil.*	There is no mention made of this bed in the District Manual, probably owing to its being so very insignificant, but as iron ore is to be had there I have entered it in this statement. The range of hills through which the bed passes is unreserved land, but has been marked off as one that should be reserved. The growth within 2 or 3 miles of the locality mostly consists of scrub fit only for fuel. The extent (approximate) may be set down at 5,000 acres and the average yield at 2 tons per acre. If worked on a rotation of 12 years which is sufficient for the regrowth of Thuringe (*Acacia amara*), the yield per annum will be $\frac{5{,}000 \times 2}{12} = 833$ tons or sufficient to manufacture a little more than 58 tons of iron.

Statement showing the number and names of the Magnetic Iron-ore beds within the Námakal talúq, the Forests nearest to them, and the probable quantity of Fuel to be had from them, etc.

Name and No. of group.	Name of Forests.	Extent in acres.	REMARKS.
	Karavalli Kombai, R. F. No 2.	8,750	The reserved and unreserved lands noted here form the whole of the Kollimalai range of hills in the Námakal talúq which, if worked on a rotation of 30 years will admit of $\frac{42{,}400}{30} = 1{,}413$ acres being felled over annually.
	Jambuthu, R. F. No. 3.	2,617	The first three, aggregating close on 17,000 acres, have been reserved under section 16 of the Act, while the others are still unreserved.
	Pulujansholai, R. F. No. 4.	5,530	The growth is very dense in parts and the average yield may be safely set down at 10 or 12 tons per
	TOTAL .	16,900	

Statement showing the number and names of the Magnetic Iron-ore beds, etc.—contd.

Name and No. of group.	Name of Forest.	Extent in acres.	REMARKS
4. Thalamalai—Kollimalai group.	Unreserved lands of the following nods:—		acre and from 5 to 6 tons if a partial clearing is made. Taking 5 tons as the outturn, the yield will be for the Reserved Forests $\frac{16,900\times 5}{30}=2,816$, which, when reduced to coal, will give a little over 700 tons. This quantity will suffice to produce nearly 220 tons of iron. The unreserved portions, if also worked on the same rotation, and if 3 tons per acre is set down as the average yield by partially working them, the outturn will be $\frac{\left(\frac{25,500}{30}\times 3\right)}{3\frac{1}{4}}-4=\frac{2,550}{4}-\frac{13}{4}=\frac{2,550}{4}\times\frac{4}{13}=196\frac{2}{13}$ tons of iron, or in all a little over 400 tons per annum. As from the District Manual, I find that the iron-beds are spread over "the whole area of the Kollimalai," all the extents noted will be within easy reach of the workings. The Belukurichi ridge, alluded to at page 101 of the Manual, lies within Mitta limits. The nearest Government jungles are on the western slopes of the Kollimalai, which, if worked, will be able to supply sufficient fuel to turn out at least 100 tons of iron annually.
	Selur nod .	6,000	
	Thevanur nod .	5,000	
	Thimmanur nod .	2,000	
	Vallapur nod .	2,000	
	Arur nod . .	3,500	
	Sundar nod .	5,000	
	Valluna nod .	2,000	
	TOTAL .	25,500	
	GRAND TOTAL .	42,400	

Statement showing the number and names of the Magnetic Iron-ore beds within the Uttankarai talúq, the Forests nearest to them, and the probable quantity of fuel to be had from them, etc.

Group, No and name	Name of Forests.	Extent in acres.	REMARKS.
5. Thirthamalai group.	Thirthamalia, R. L. 78.	11,046	Of the forest noted in column 2 the fourth known by the name of "Puvampatti" has been declared a Reserved Forest under section 16, while the first three are under settlement, and will ere long be also reserved under above section of the Act. Their total area (approximate) is 27,846 acres = 43·5 square miles. The remaining nine extents are unreserved lands aggregating about 4,100 acres, or 6·4 square miles, so that the total extent from which fuel may be had ***within a radius*** of from 5 to 6 miles of the Thirthamalai magnetic iron beds is 49·9 square miles, or nearly 32,000 acres. The reserved forests contain far better growth than the unreserved portions. If the former are worked on a rotation of 20 years, they will allow of nearly
	Veppampatti, R. L 79.	8,640	
	Poyipatti, R. L. 75 .	3,488	
	Puvampatti, R. L. No. 50.	4,672	
	TOTAL .	27,846	
	Unreserved lands of the following villages:—		
	Endalur . .	500	

Statement showing the number and names of the Magnetic Iron-ore beds, etc.—contd.

Group, No and name	Name of Forest,	Extent in acres.	REMARKS.
	Peria Pouni Maduvu.	800	1,400 acres being felled annually. If a clean felling is carried on, the annual yield will not be less than from 7,000 to 8,000 tons of fuel On the other hand, if only a partial cleaning is undertaken, that is, after reserving all good timber, trees and saplings of good description and straight growth, then the yield will probably not be more than one-half the above figure, or say, 4,000 tons. As 4 tons of wood are required to give one of charcoal, the outturn of that product will be $\frac{4,000}{4} = 1,000$ tons. This quantity will admit of producing a little over 307 tons of iron (*vide* remarks on page 99 of the Manual).
	Srima Pouni Maduvu.	800	
	Kalla vudichampatti.	1,000	
	Tambal . .	300	
	Malasingambadi	200	
	Audiyur . .	200	
	Mondukuli .	100	
	Alambadi . .	200	The unreserved extents, aggregating 4,100 acres, also contain in parts very good growth. The average yield per acre may be set down at 3 tons, that is, if a clean cutting is made, otherwise about 2 tons only taking the last figure for the purpose of arriving at the quantity of fuel that may be had, and working the extents on the same rotation as noted above, we will get $\frac{4,100 \times 2}{20} = 410$ tons per annum; this quantity will allow of a little over 126 tons of iron being made, or a total of 433, or, say, 440 tons annually.
	TOTAL .	4,100	If jungles lying 2 to 3 miles east-north-east and south of the present Thirthamalai reserve are also worked for fuel, on the above rotation, from 2,000 to 2,500 more tons may be had annually, which produce $\frac{2,500}{\times 3\frac{1}{4}} = 192\cdot3$ tons of iron.
	GRAND TOTAL .	31,946	W CARROLL, *Acting District Forest Officer,* G. STOKES, *Collector.*

Casuarina and blue-gum plantations.

The luxuriance with which *Casuarina* grows in suitable places exposed to moist sea-air, as on the coast of Nellore, Chingleput, and South Arcot, will possibly, according to Sir D. Brandis, be a means of reducing the price of fuel sufficiently for its profitable conversion into charcoal.[1] He makes similar remarks concerning the fast-growing *Eucalyptus* of the hills. Although the increased yield per acre of timber available for fuel will undoubtedly bring down the price, I do not think it is so certain that fast-growing trees like *Casuarina* and the blue-gum will produce timber suitable for charcoal-manufacture. Without doubt they would replace, as fuel for the railways and towns, those *hard timbers* which are found to be suitable for charcoal, and so, indirectly, the cost of the carbonised product becomes reduced.

Slow-growing timbers.

As to the nature of the wood necessary to produce a good charcoal for smelting purposes we are comparatively in the dark. By experience the natives have discovered the preferable qualities of the

[1] Suggestions regarding Forest Administration in the Madras Presidency (1883), p. 54.

woods,—*irúl, wúnjai, sambalichan, nekani*, and *oodavai*, and of these they show, in the Salem district and in Malabar, a distinct preference for the first two. The utmost we know of these woods is that they are all hard, close-grained woods; but, as to any other properties which give them their excellent charcoal-producing qualities, as yet we know nothing. The fact that they are all hard and comparatively slow-growing woods, suggests the conclusion that these are desirable properties probably on account of (1) the firmness of the carbonised product, and (2) the small percentage of ash which slow-growing woods generally leave on ignition.

Relation between annual yield and quality of charcoal.

If in general, slow-growing woods produce the best charcoal, we have the problem to solve of choosing between annual yield on the one hand and quality of product on the other. I do not, however, conclude from the mere fact of the native smelters preferring these hard woods, that only such wood gives the best kind of charcoal. As I have before stated, we are in comparative ignorance on the subject, because, as far as I know, no experiments have been made as to the amount of ash, calorific power, strength of product, or other properties, which are the test of a good charcoal. If it can be proved that *Casuarina*, and fast-growing trees in general, possess the characters of good charcoal-producers the course to pursue is obvious. To show this is the problem, and I am confident that it is one most easily and inexpensively solved. For this purpose I would suggest that a collection of the principal South Indian timbers be made, say four or five samples of each kind, selected from different localities, and that the ash, the calorific intensity and power, and quality of the charcoal produced be determined. The facts are of the simplest possible nature to ascertain, and the data so obtained will stand without question or modification as a permanent guide in the selection of a timber which combines, with a large annual yield, a suitable charcoal for smelting purposes, and, what must follow as a natural consequence, a good fuel for locomotive and domestic use.

Proposed collection of certain South Indian timbers for determination of ash, etc.

Styrian and American charcoal-burners and smelters.

Combined with this addition to our knowledge, it would be a decided advantage if an officer with a sufficient metallurgical training, could pay a short hot-weather visit to some continental or American iron-smelting locality, where charcoal is used (as in the Styrian process, which most nearly resembles that of the Salem steel-makers), for the purpose of examining the particulars of the processes, both of charcoal-burning and of iron- and steel-manufacture, and to collect either specimens or data of the fuel for comparison with the Indian timbers. A metallurgist, who has learnt his theory and practice in England, having paid exclusive attention to factories worked with coal alone, feels incompetent to give reliable advice on the nature of the timbers to be grown, or methods which are likely to be successful in iron-smelting with charcoal-fuel. Experiments on the native processes will be tedious, as well as unsatisfactory, and whilst to any one who has an elementary acquaintance with the principles and practice of metallurgy, the native methods of both charcoal-burning and iron-smelting are wasteful of material and uncertain in result, I would most decidedly not recommend the adoption of any improvement suggested from mere acquaintance with theoretical principles. A simple visit to a charcoal-burning and smelting locality will enable a metallurgist to offer the advice which will settle once

Improvement of native processes.

for all the question as to the possible development of the enormous iron-resources in this presidency; and considering the amount of money already lost in aiding unsuccessful companies, it will be a most profitable way of spending a hot season. In this, of course, I am taking for granted, as I believe it to be the case, that the use of coal for the Salem ores is quite out of the question. The only hope, as far as I can see, is the employment of charcoal of the right kind, and with the most economical process.

Warth's analyses of ashes.

Hitherto the only data of the above nature, as far as I can find, on Indian timbers are the instructive results obtained by Dr. H. Warth in the examination of the ash of twenty-six woods; but these are principally of more northerly growth.[1] Although Dr. Warth gives only the amount and composition of ash of these timbers, the results are sufficient to show the wide variation there is between the relative qualities of these timbers as fuels, and in a quadruple degree, as charcoal-fuels. *Bauhinia Vahli*, the *Maljhan*, gives for example an abnormal ash of 11·74 per cent., and its very slow-burning properties make it just a convenient log to inspire the story-telling fakír! The ash, of course, not only affects the rate of combustion, but, from the specific heat of the inorganic material, is a considerable source of loss in heat, besides, in iron-smelting, introducing bases which have a decided effect on the quality of the iron and steel produced.

Slow-burning timber.

Sir D. Brandis' proposal of *Casuarina* and *Eucalyptus* plantations.

In his exhaustive report on the Forest Administration in the Madras Presidency, Sir D. Brandis details the evidence which leads him to conclude that the forests may be developed greatly to the advantage of the iron-industry, but before cultivating, as he advises, the fast-growing *Casuarina* and blue-gum, I would suggest the precaution of ascertaining whether these, or what, trees are capable of producing a suitable charcoal for iron-manufacture; and, for this purpose, it is necessary, as Dr. Brandis reiterates in many places, to attach a competent metallurgist who has had practical acquaintance with charcoal iron-smelting, either to the Forest Department or to the Geological Survey in Madras. This might easily and inexpensively be brought about in the manner indicated above, and my remarks on Kanjamalai are, I hope, sufficient to show that we are by no means sufficiently acquainted with the mineral resources of Salem to allow of an unqualified condemnation of any attempt to develop its immense iron-deposits.

Dr. Brandis' proposal to attach a Metallurgist to the Forest Department or Geological Survey.

VII.—Conclusions on the questions affecting the development of the industry.

The conditions which will affect the possible development of the iron-manufacturing industry in the Salem district may be arranged under the following heads:—

(*1*) *Resources of iron-ore.*

[1] Manual of Natural Sciences for the use of students in the Forest School, Dehra Dun, Calcutta, 1886, pp. 184, 185.

(2) *Supply of auxiliary ores of—*
(*a*) Chromium.
(*b*) Manganese.
(*c*) Titanium.
(*d*) Aluminium.
(*e*) Tungsten.
(3) *Fuel supply.*
(4) *Smelting methods.*
(5) *Bye-products.*
(6) *Market.*[1]

For the reasons detailed in the preceding pages I beg to submit the following conclusions and suggestions under these heads:—

(1) *Resources of iron-ore.*—These are without question undoubted in quantity, and I may say also in quality; but a statement of the exact amount of iron yielded by an average sample of ore I hope to embody in my final report, together with the results of a careful search for phosphorus, sulphur and other elements which have such a pronounced effect on the quality of the iron and, especially, of the steel produced.

(2) *Supply of accessory ores—*

(*a*) *Chromium.*—The great and increasing demand for this metal as an advantageous addition to steel has been indicated in a previous page (p. 140). I have recorded, also, my reasons for the probability of additional occurrences of chromite in the Salem district, and would suggest that a search for this mineral be instituted at the north-west base of Kanjamalai and in other localities which present the petrological characters already stated as favourable to the occurrence of this mineral.

(*b*) *Manganese.*—With regard to this mineral there is no definite evidence to offer as to its occurrence within the limits of this district, beyond the fact of its frequent association with, and sometimes in, iron-ores. Chemical examination of the specimens collected will throw some light on this question.

(*c*) *Titanium.*—Newbold's discovery of this metal in the iron-ores of Salem suggests a careful search for its minerals. It has been pointed out that the metallurgical advantages arising from the use of titaniferous iron-ore are as yet doubtful, but they seem to bear more on the conditions of smelting rather than any alloyed product (*vide* p. 139). They are used largely in Sweden and in Ontario with minerals of the same nature, and obtained from the same class of metamorphic rocks, as those of Salem.

(*d*) *Aluminium.*—The deposits of corundum have long been known. Should a cheaper method of manufacture be invented, or some natural source of power, like falling water, be employed with present methods, as recently suggested by Mr. A. Chatterton, the value of this metal, though questionable as an advantageous introduction to steel, is, for other purposes, undoubted. The very high price of aluminium and the demand which this useful metal is, from its exceptional

[1] The demand for iron is too well secured to call for remark on this head.

properties, bound to secure, make this point decidedly worth attention. I would call attention to Mr. Chatterton's scheme for utilising the great water-power of South India for the manufacture of aluminium, and at the same time suggest a careful survey of the valuable corundum-deposits of the districts of Salem, Coimbatore, and North Arcot, as well as Mysore; and that a further search for the minerals cryolite and bauxite be made. Lacroix's paper in Volume XXIV of the Records of the Geological Survey of India proves that we are as yet unacquainted with the variety of minerals in the crystalline rocks of Salem, and he has especially offered some suggestive points on the paragenesis of corundum.

(*e*) *Tungsten* —This metal is occasionally used in steel to impart hardness to the alloy, the steel taking a fine damask According to Vosmaer it is often found in wootz. This is another point to be decided by chemical examination of the specimens.

With regard to the whole question of the alloying of iron with the metals referred to above, it may be remarked that the recent discoveries of Hadfield, Roberts-Austen, and others of the remarkable properties of iron-alloys indicate a probability of considerable development in this respect.

(*3 Fuel supply.*—As the supply of coal seems to be out of question, the fuel must be entirely charcoal. Under this head has been given a summary of our present knowledge concerning the kinds of timber preferable for the manufacture of charcoal for iron-smelting, and for ordinary fuel on the railway and in towns. I have also given reasons for suggesting the determination of the ash, calorific power and other properties of selected South Indian timbers as necessary preliminary data for carrying out Dr. Brandis' suggestion of increasing the yield by *Casuarina* and blue-gum plantations. The suggestion of Dr. Brandis to attach a metallurgist, having practical acquaintance w'th charcoal iron-smelting, to the Forest Department may, I believe, be most inexpensively carried out by deputing an officer for a few months only to the charcoal-burning and smelting localities of Styria or America, for the purpose of examining the processes of preparing the charcoal and smelting the ore in a manner which has proved to be commercially successful. Such an officer will be able to apply the experience of the charcoal-burners to the facts obtained in the laboratory as to the value of the different woods for iron-smelting, and to offer advice which ought to settle the question, once for all, of the practicability of (*a*) forest development, (*b*) charcoal-burning and its bye-products—pyroligneous acid and the results in general of dry, destructive distillation of wood, (*c*) improving, or replacing by European processes, the native methods of smelting, and (*d*) the utilisation of the accessory ores of chromium, manganese, titanium, aluminium, and tungsten.

(*4*) *Smelting methods.*—The present mode of native smelting is attended with an enormous waste of heat, ore and labour in the blast-producing. In estimating the furnace-charge by pure guess-work, there is not only a waste of material, but a highly detrimental uncertainty of result. Although the manufacture of wrought iron by the direct process is open to many drawbacks, it must be admitted that the use of charcoal, on account of its regular purity, removes one important objection. The manufacture of steel by the preliminary production of pig-iron in small

furnaces has been suggested by Dr. Waith, and, according to Mr. Heath, some such process was at one time employed by the natives; but none of the present pariah workers seem to be acquainted with the practice.

Without doubt the absurd blowing apparatus can be improved with advantage, and numerous other improvements suggest themselves to any one acquainted with metallurgy, but I would strongly urge the importance of not tampering with the present methods except under advice of a metallurgist who has seen something of charcoal iron-smelting in addition to the education which an English metallurgist receives in places where coal is the only fuel employed.

In mining and dressing the ore the native methods are even less economical than in the smelting. Because of their friability decomposed pieces of ore only are selected, and from these a large quantity of limonite and quartz has to be separated, whilst richer ore, on account of its superior hardness, is rejected.

Madras, February 29th, 1892.

On the Occurrence *of* Riebeckite *in* India, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India.*

History of riebeckite.

In 1882 Professor T. G. Bonney, in a paper to the Royal Society describing a series of rock-specimens collected by Professor Bayley Balfour on the island of Socotra, referred to the occurrence in one of the granitoid rocks of a mineral which, whilst presenting many of the characters of members of the amphibole-group, he, apparently with some hesitation, referred to tourmaline, regarding it as pseudomorphous after hornblende.[1]

In 1888 the same author described "a peculiar variety of hornblende from Mynydd Mawr, Carnarvonshire," which in general appearance and in optical characters resembled the Socotra mineral.[2] He classed this mineral with the hornblende-group, and on account of a communication from Professor Sauer of Leipzig, who had isolated and analysed a similar mineral, referred it, apparently not without some misgivings, to arfvedsonite (*cf.* footnote, *op. cit.*, p. 106).

Independently Mr. A. Harker had been studying the Mynydd Mawr 'porphyry,' and had also described the peculiar blue mineral as hornblende.[3]

Professor A. Sauer of Leipzig noticed amongst a series of rocks collected by Dr. E. Riebeck, on the island of Socotra, the blue mineral previously mentioned by Professor Bonney. From its optical characters and from the chemical analysis of the isolated mineral, Sauer, independently of both Professor Bonney and Mr. Harker, referred it to the hornblende-group as a new variety under the name of *riebeckite.*[4]

It seems that, whilst this mineral in many respects resembles arfvedsonite, it differs in the fact that most of the iron entering into its composition exists in ferrous combinations,[5] and it appears from Rosenbusch's description,[6] that the axis of

[1] *Phil. Trans.*, vol. 174 (1883), p. 283, and pl. VII.
[2] *Min. Mag.*, vol. VIII, p. 105.
[3] *Geol. Mag.*, dec. III, vol. V (1888), p. 225.
[4] *Zeitschr. der Deutsch. geol. Gesell.*, vol. XL (1888), pp. 138-146.
[5] *Ibid.*, p. 143.
[6] *Ibid.*, pp. 143 and 144.

optical elasticity which makes an angle of 5° with the vertical crystallographic axis, *c*, is α and not γ, as is usual with the amphiboles. In this respect, as well as in the condition in which the iron exists, it resembles ægirine of the augite-group, and thus contributes to the completion of the parallelism between the amphiboles and the pyroxenes.

Since the publication of the above-mentioned researches, riebeckite has been recognised in a Corsican granulite by M. U. LeVerrier,[1] and in a rock from Colorado, which M. A. Lacroix would regard as an elæolite-syenite in which the quartz replaces nepheline[2]; in a micro-granite from Ailsa Craig, by Mr. J. J. H. Teall;[3] in eurite-pebbles found by Mr. P. F. Kendall in the glacial drift of the Isle of Man and on Moel-y-Tryfan by Professor Grenville A. J. Cole.[4]

The present note records the occurrence of this interesting mineral in India. The rock in which it occurs was discovered by Mr P. N. Bose as an intrusive boss in the slates of Daling age[5] between Song and Tikobu, Southern Sikkim.[6]

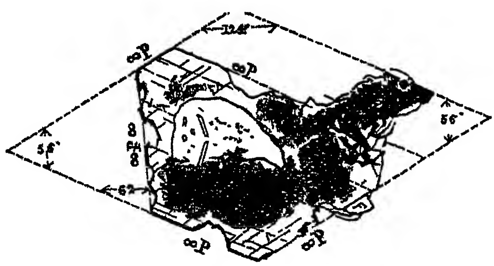
It is a compact, fine-grained rock, almost slate-grey in colour when fresh, but weathering to a pale brown on exposure. Its specific gravity is 2·78.

Under the microscope thin sections exhibit quartz, orthoclase, microcline, oligoclase, biotite, riebeckite, sphene, zircon, magnetite, titanoferrite, and, perhaps, apatite.

Optical properties.

The riebeckite occurs in crystals seldom exceeding ·034 inch (·08 cm.) in length and, more rarely, as much in diameter. From the way in which they have been interrupted in their growth by neighbouring quartz- and felspar-crystals, they rarely present recognisable idiomorphic outlines, but frequently exhibit a feeble attempt at ophitic development. The optical characters and the characteristic cleavage of amphibole (see figure) demonstrate satisfactorily the identity of this mineral with Sauer's riebeckite. The pleochroism is—

α, indigo-blue.
$\beta(=\mathfrak{b})$, deep blue.
γ, yellowish green.



Horizontal Section of Riebeckite.

[1] *Comptes Rendus*, vol. CIX (1889), p. 38.
[2] *Ibid.*, vol. CIX (1889), p. 39.
[3] *Min. Mag.*, vol. IX (1891), p. 219.
[4] *Ibid.*, vol. IX (1891), p. 222.
[5] The name applied by Mr. F. R. Mallet to a group of sub-metamorphic rocks in the Darjeeling district. (*Mem., Geol. Surv., Ind.*, vol XI (1874), p. 12).
[6] Bose: *Rec., Geol. Surv., Ind.*, vol. XXIV (1891), p. 222.

The angle between the vertical crystallographic axis *c* and *a* gave 9° as an average of twelve measurements varying from 7° 30' to 10°,—the intense absorption making the measurement of extinction a matter of considerable difficulty. This result gives a wider angle than that obtained by Sauer, who found that in the Socotra mineral the extinction-angle was about 3—4°, whilst Rosenbusch gave it as 5°.[1]

Inclusions in riebeckite.

Almost every riebeckite crystal is opaque in the centre. This is sometimes due to a nucleus of magnetite around which the mineral has grown; but occasionally this core is seen to be almost white by reflected light, and I could not decide whether it was due to original opaque inclusions or to the results of secondary alteration. The fragmentary state of the crystals and the large quantities of these opaque inclusions would make a chemical analysis of little value, even should it be possible to separate crystals so small from other heavy ferro-magnesian silicates in the rock. Besides the larger crystals, minute lath-shaped and rod-like crystals presenting similar optical properties occur in the matrix, and are presumably also riebeckite-crystals.

The remaining constituents already enumerated make, with riebeckite, a rock which might be classed as a *granitite.*

As in all cases previously recorded, riebeckite appears as a constituent of an igneous rock, and accompanied also by zircon and sphene. The mineral recalls in some respects the beautiful crystals of glaucophane, which seem to occur, on the contrary, only as a constituent of undoubted metamorphic rocks.

Paragenesis of riebeckite.

In the granulite described by M. Le Verrier from Corsica, riebeckite occurs associated with the zircon and titanium-bearing mica, astrophyllite; in the Colorado rock described by M. Lacroix, it is associated with astrophyllite and pyrochlore—a columbate of lime and cerium. In this rock, found by Mr. Bose, and in nearly all cases hitherto recorded, zircon- and titanium-bearing minerals seem to accompany riebeckite. This association with the so-called rare metals (whose habits are daily becoming more familiar to mineralogists and chemists) seems to be a point worthy of attention: it seems likely that before long a mineral, more so than a man, will be known by the company it keeps, and it will please the curious to discover the qualifications by which an *entrée* is obtained to the select circles of Brevig and Friederichsvärn in Norway, Miask in the Urals, and, soon we shall be able to say, Salem in Madras.

Coal *on the* Great Tenasserim River, Mergui District, Lower Burma, *by* T. W. H. HUGHES, *Superintendent, Geological Survey of India.*

The announcement of the discovery of coal on the Great Tenasserim River prompts me to point out that many years ago, and soon after our occupation of the Siamese districts which we had wrested from the Burmans, the existence of coal at various spots on the Great Tenasserim River was made known.

[1] Sauer: *op cit.*, pp. 143 and 144.

Amongst the first explorers of the country, the chief ones were Dr. Holfer in 1838, Captain G. B. Tremenheeie in 1841, and Dr. Oldham in 1855. The latter gives a list of places where coal occurred in the Great Tenasserim valley :—

Heinlap,	Hinlat,
Kanmapying,	Kaw-ma-pyin,
Pawort,	Pawút,
Thatay-hkhyoung,	Kyauk-mi-thwe,

and he describes the coal-seam that was worked experimentally in 1843, and which is alluded to as the Thatay-hkhyoung coal Kyauk-mi-thwe coal or Thendaw coal, in the various publications and official papers referring to it.

The discovery of coal, therefore, this year is a re-opening, and is only so far new, in that coal has been proved at another point.

It was deemed advisable, while carrying on prospecting operations for minerals generally in the Mergui district, to furbish our information while the means for doing so were at hand,—and perhaps by calling attention once again to the value of the Tenasserim coal-field, afford an opportunity to mining venturers of satisfying their ruling taste.

The coal tested by our party, crops out in the Hti-phan-ko stream, a tributary on the right bank of the Great Tenasserim River, 24 miles due east of the town of Mergui. Two pits were sunk on the seam by Mr. Alexander Primrose, who had charge of the prospecting operations, and the section is, descending—

Surface soil, etc.—

Coal	0′	10″
Shale	2′	0″
Coal	2′	3″
Shale	3′	0″
Coal	4′	6″
Total seam	12	7
„ coal	7	7

The angle of dip is high, being as much as 32°. Direction, slightly S. of E.

Analyses of three samples, two (A and B) from the upper 2′ 3″ layer, and one (C) from the bottom 4′ 6″ bed, have been made by Mr. T. H. Holland, Curator of the Geological Museum, and the results are :—

	Specimen "A"	*Specimen "B."*	*Specimen "C."*
Moisture	15·20	10·80	11·34
Volatile matter	30·08	27·36	36·40
Fixed carbon	30 86	42·52	43·27
Ash	23 86	19·32	8·99
	100·00	100·00	100·00
	Does not cake.	Does not cake.	Does not cake.
	Ash, reddish brown.	Ash, reddish brown.	Ash, reddish brown.

SPECIMEN A.—Fissile parallel to the planes of stratification, the cleavage-planes being dull, possibly from films of argillaceous material. Fracture across the bedding planes, rather uneven, and, where carbonaceous matter is more concentrated, feebly conchoidal; these surfaces exhibit a shining lustre.

SPECIMEN B.—Similar physical characters to A.

SPECIMEN C.—Breaks in all directions with a conchoidal fracture, the surfaces invariably exhibiting a shining lustre. None of the specimens soil the fingers, in this respect differing from most of the Indian coals of younger age.

The bottom coal (specimen C) is the one I would more particularly call attention to, as it is a hard jetty variety, well fitted to stand the wear and tear of transport, and contains very little pyrites.

Trials were made to test its efficiency in the Government steam launch *Mergui*, and it gave satisfactory results, there being no difficulty with untrained firemen in raising and keeping 95lb of steam on a long course. There was a little clinker.

The commercial value of the Tenasserim field depends, as I am aware, upon questions other than those of the mere quality or quantity of the coal, but it is a strong point in its favour when the coal is above the average Indian standard, as this is.

The locality in which it occurs is unfortunately situated for labour transport and shipment, disabilities representing a less profit to lessees. But I think the following estimate will cover the charges for one ton of coal at the pit side, on an out-put of 10,000 tons a year:—

	R	a.	p.
Labour	2	8	0
Stores	1	0	0
Establishment and supervision	1	0	0
Haulage and contingencies	1	0	0
Royalty	0	4	0
	R 5	12	0

Transport to Mergui, R2-0-0.

A market other than the local one must be found. Two exist, in Rangoon and Penang, in both of which there would be a large sale for a good steam coal at low rates.

What I have written is simply to recall the fact that there is coal on the Great Tenasserim River, and it rests with those who may be inclined to embark in coal-mining to make such personal investigations as will satisfy themselves that the prospects of success are promising or otherwise.

The quantity of coal is abundant; and so soon as the map prepared this season by the Topographical Survey is issued, the proximate boundaries of the field will be marked, and a fuller paper with a coloured map will be published.

1st July, 1892. T. W. H. HUGHES.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 12.—Ending 31st July 1892.

Director's Office, Calcutta, 31st July 1892.

The Director, Dr. W. King, having taken privilege leave from the 24th of June last, Mr. T. W. H. Hughes has been appointed to officiate during the Director's absence.

In the present number of the Records Mr. Hughes has given an account of the occurrence of coal on the Great Tenasserim River, Mergui district, South Burma.

Mr. Griesbach and Dr. Diener left Calcutta on the 12th of May and were joined by Mr. Middlemiss at Naini Tal. The party proceeded *viâ* Almorah for the purpose of working out the palæontology and stratigraphy of the triassic rocks in the Central Himálayas.

Mr. LaTouche has made a report on the oil-springs near Moghal Kot in the Shirani country, with a description of the stratigraphical characters of the oil-bearing and associated rocks. Specimens of the oil collected at two points of outflow have been examined in the laboratory by Mr. Holland. One of the samples (A) exhibited certain chemical characters markedly like those of the specimen collected by Mr. Oldham two years ago, but the latter had lost its more volatile hydrocarbons by exposure in a shallow pool. By subjecting the former to artificial exposure, in imitation of the natural conditions, the volatile naphthas disappeared, and the residue gave a flashing point, specific gravity and fractional distillation strikingly near those of Mr. Oldham's specimen. The chemical results confirm also the opinion expressed by Dr. Warden in 1890 that "a large supply of a natural oil of this quality would simply drive all foreign oils out of the market." But Mr. LaTouche confirms the statement previously made by Mr. Oldham as to the limited supply of the oil, and in his report on the subject, which will be published in the next part of the Records, he makes certain suggestions for the purpose of obtaining a larger flow than that now obtainable at the surface.

Mr. Mallet, late Superintendent in this Department, shows his continued interest in Indian mineralogy by generously following up his translation of Lacroix's petrological researches on certain South Indian and Cinghalese rocks, with an interesting contribution clearing up the difficulties with regard to the locality of the mineral *tscheffkinite* (*vide* p. 123). The occurrence of this comparatively rare mineral on Kanjamalai in the Salem district, interestingly coincides with Mr. Holland's reference to the hypersthene- and olivine-bearing ultra-basic and other igneous rocks which have disturbed the rich iron-ore beds on the north-western slopes of the

same hill. These facts, together with the petrological work of M. Lacroix published in the last volume, lend some support to the expectation that Salem district will some day prove as rich in mineral variety as the natural museums of Norway and the Urals.

Amongst the features of interest noticed by Mr. Datta in his examination of the Sagaing district in Burma may be mentioned the occurrence of nodular iron-pyrites in sandstones, which the natives of the district formerly employed as a source of sulphur for the manufacture of their gunpowder. Mr. Datta is preparing a report on his work in this and in the Pakokku and Thayetmyo districts.

The nodules collected near Utatur in the Trichinopoly district by Dr. Warth contain, as he suggested, large proportions of phosphoric acid. Specimens analysed in the laboratory yielded on an average nearly 60 per cent. of phosphate of lime. Although the value of phosphates has lately been considerably depreciated on account of the finds in Algeria and Florida, the Trichinopoly deposit ought to prove of service on the southern tea and coffee plantations when converted into superphosphate; and there seems no reason why sulphuric acid should not be manufactured in India for such a purpose.

List of Reports and Papers sent into the Office for publication or record during May, June and July 1892.

Author.	Subject.	Disposal.
THEO. W. H. HUGHES .	Coal on the Great Tenasserim River, Mergui district, Lower Burma.	Appear in the current Records, Geological Survey of India.
C. L. GRIESBACH . .	Geological sketch of the country north of Bhamo.	
FITZ. NOETLING . .	Preliminary Report on the economic resources of the Amber and Jade Mines area in Upper Burma.	
T. H. HOLLAND . .	Preliminary Report on the Iron-ores and Iron-industries of the Salem district.	
T. H. HOLLAND . .	On the occurrence of Riebeckite in India.	
T. H. HOLLAND . .	The Iron-ores and Iron-industries of the southern districts, Madras Presidency.	To appear as a preliminary hand-book for Imperial Institute.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June and July 1892.

Substance.	For whom.	Result.
Three specimens of phosphatic nodules from Utatur, Perambular taluq, Trichinopoly district.	Dr. H. WARTH, Officiating Superintendent, Government Central Museum, Madras.	Specimen "A"— Quantity received 12 lb. Contains 23·54 % phosphoric anhydride (P_2O_5). Specimen "B"— Quantity received 1¾ oz. Contains 30·9 % phosphoric anhydride (P_2O_5). Specimen "C"— Quantity received 9¼ oz. Contains 26·12 % phosphoric anhydride (P_2O_5).
One specimen of quartz .	OCTAVIUS STEEL & CO., Calcutta.	Assayed for gold and silver.
One specimen of graphite	STEEL BROS. & CO., Ld., Rangoon.	Carbon determined.
One specimen of "earth for analysis" from His Highness the Amir of Afghanistan.	WALSH LOVETT & CO., Calcutta.	=Lignite. (Peat passing into lignite, with roots of plants and a large number of fresh-water shells.)
One specimen of galena with quartz.	F. W. HEILGERS & CO., Calcutta.	Assayed for lead and silver.
One specimen of quartz, "No. 16."	BARRY & CO., Calcutta .	Assayed for gold and silver.
One specimen of iron pyrites with quartz from Nantyok, Henzai, Tavoy district, Burma, for gold.	P. N. BOSE, Geological Survey of India.	Contains no gold.
Two specimens of "quartz"	F. W. HEILGERS & CO., Calcutta.	=Talc-schist with pyrites. Assayed for gold and silver.
Three specimens of coal, from Kaw-ma-pyn, Great Tenasserim valley, Burma.	T. W. HUGHES, Geological Survey of India.	Specimen "A" (Upper seam)— Quantity received 1½ lb. Moisture . . . 15·20 Volatile matter . . 30·08 Fixed carbon . . 30·86 Ash . . . 23·86 ————— 100·00 Does not cake. Ash—reddish brown. Specific gravity, 1·47.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July, 1892—continued

Substance.	For whom.	Result.
		Specimen "B" (Upper seam)—Quantity received 2lb. Moisture . . . 10·80 Volatile matter . . 27·36 Fixed carbon . . 42·52 Ash . . . 19·32 100·00 Does not cake. Ash—dark reddish brown. Specific gravity 1·40. Specimen "C" (Lower seam)—Quantity received 1½lb. Moisture . . . 11·34 Volatile matter . . 36·40 Fixed carbon . . 43·27 Ash . . . 8·99 100·00 Sinters slightly. Ash—reddish brwon.
Two specimens of quartz, Nos 2 and 3, from the Kedanak mines, Mount Ophir, Johore.	BARRY & Co., Calcutta .	Assayed for gold and silver.
One specimen from the Dundot colliery.	W. B. D. EDWARDS, Geological Survey of India.	Clay.
Two specimens from Nantyok, Henzai, Tavoy district, Burma.	P. N. BOSE, Geological Survey of India.	Pyrites with sulphate of iron efflorescence. Mispickel.
Two specimens from Dehra Doon, N.-W. Provinces.	W. POULTER, Mussoorie	No. I.—Fine powder composed of clay, minute sand grains, and powdered pyrites. No. II—Sand. quartz, gralar, mica hornblende and pyrite.
One specimen from Baluchistan.	Executive Engineer, Public Works department (Zhob division), Fort Sandeman.	Iron pyrites.
One specimen from Doddancombai forest, Satyamangalam taluq, Coimbatore.	District Forest Officer, Coimbatore.	Magnetite.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July, 1892 —concluded.

Substance.	For whom.	Result.
One specimen . .	J. JARBO, Sub-Divisional Officer, Bandarban, Chittagong Hill Tracts.	Sulphate of alumina and sulphate of iron, with traces of lime.
One specimen . .	MACTAVISH & Co., Calcutta.	Bitumen (asphalt).
	Bengal Coal Company, Calcutta.	Coal. Specific gravity, 1·38.

Notification by the Government of India during the months of May, June, and July 1892, published in the "Gazette of India," Part I.—Leave.

Department.	Number of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	Remarks.
Revenue and Agricultural Department.	$\frac{1070}{120}$, Surveys, dated 31st May 1892.	WILLIAM KING	Privilege.	25th June 1892.	...	

Notifications by the Government of India during the months of May, June and July 1892, published in the "Gazette of India," Part I. —Appointment, Confirmation, Promotion, Reversion and Retirement.

Department.	Number of order and date.	Name of officer.	From	To	Nature of appointment, etc.	With effect from	Remarks.
Revenue and Agricultural Department.	$\frac{1072}{120}$, Surveys, dated 31st May 1892.	Theo. W. H. Hughes.	Superintendent.	Officiating Director.	Acting, temporary.	25th June 1892.	
Ditto .	$\frac{1465}{8}$, Surveys, dated 14th July 1892.	H. B. W. Garrick.	Artist .	...	Substantive.	1st July 1891.	

Annual Increments to graded Officers sanctioned by the Government of India during May, June and July 1892.

Name of officer.	From	To	With effect from	No. and date of sanction.	Remarks.
	R	R			
R. D. OLDHAM . . .	850	900	1st May 1892.	Revenue and Agricultural Department, No. $\frac{1351}{140}$, Surveys, dated 1st July 1892.	
W. B. D. EDWARDS . .	350	380	6th June 1892.	Revenue and Agricultural Department, No. $\frac{1456}{147}$, Surveys, dated 14th July 1892.	

Postal and Telegraphic Addresses of Officers.

Name of officer.	Postal address.	Nearest Telegraph office.
T. W. H. HUGHES . . .	Calcutta	Calcutta.
C. L. GRIESBACH . . .	Almora, N. W. P. . .	Almora.
R. D. OLDHAM	Calcutta	Calcutta.
P. N. BOSE	Do.	Do.
T. H. D. LATOUCHE . . .	Kulu	Kulu.
C. S. MIDDLEMISS . . .	Almora, N. W. P. . .	Almora.
W. B. D. EDWARDS . . .	Murree	Murree.
P. N. DATTA	Calcutta	Calcutta.
F. NOETLING	Mandalay	Mandalay.
HIRA LAL	Dakha	Ludhiana.
KISHEN SINGH	Mandra	Mandra.

DONATIONS TO THE MUSEUM.

FROM 1ST MAY TO 31ST JULY 1892.

1 Box of fossils.

PRESENTED BY H. B. ADDIS, EXECUTIVE ENGINEER, MID-INDUS DIVISION, FRONTIER RAILWAY.

Sheets of muscovite, from the Gya District.

PRESENTED BY E. T. HOLLINGSWORTH, CALCUTTA.

1 specimen of fuller's earth.

PRESENTED BY COL. D. G. PITCHER, DEPARTMENT, LAND RECORDS, GWALIOR STATE.

2 specimens of iron pyrites, from the Simla District.

PRESENTED BY A. R. TUCKER, REGISTRAR, REVENUE AND AGRICULTURAL DEPARTMENT, SIMLA.

1 specimen of anhydrite and gypsum, from the brick-red gypsum above the Rock Salt Mayo Mines, Punjab.

PRESENTED BY DR. H. WARTH, OFFICIATING SUPERINTENDENT, GOVERNMENT CENTRAL MUSEUM, MADRAS.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1892.

Titles of Books. *Donors.*

BLAIR, *A. A.*—Chemical Analysis of Iron. 2nd Edition. 8° Philadelphia, 1891.

BOUTAN, *M. E.*—Le Diamant. 8° Paris, 1886.

BRONN'S Klassen und Ordnungen des Thier-Reichs. Band IV, lief 18-20. 8° Leipzig, 1892.

FORBES, *Dr. Duncan.*—Dictionary of Hindustani-English and English-Hindustani, 8° London, 1858.

GARROD, *Sir A. B.*—The Essentials of Materia Medica and Therapeutics. 8° London, 1892.

GROTH, *P.*—Physikalische Krystallographic. 8° Leipzig, 1885.

HOWE, *H. M.*—The Metallurgy of Steel. Vol. I, 2nd Edition. 4° New York, 1891.

KLEIN, *Dr. H. J.*—Jahrbuch der Astronomie und Geophysik. II Jahrgang, 1891. 8° Leipzig, 1892.

LÉVY, *A. Michel,* and LACROIX, *Alf.*—Les Minéraux des Roches. 8° Paris, 1888.

LOCK, *C. G. Warnford.*—The Miners' Pocket Book. 8° London, 1892.

MILL, *H. R.*—The Realm of Nature: an outline of Physiography. 8° London, 1892.

MILLS, *E. J.*, and ROWAN, *F. J.*—Chemical Technology or Chemistry in its application to Arts and Manufactures, Vol. I. 8° London, 1889.

RANKINE, *W. J. W.*—A Manual of Civil Engineering, 18th Edition. 8° London, 1891.

ROSCOE, *H. E.*—Lessons in Elementary Chemistry, Inorganic and Organic. New Edition. 8° London, 1891.

SUTTON, *Francis.*—A systematic Handbook of Volumetric Analysis. 6th Edition. 8° London, 1890.

TRYON, *George W. J.*—Manual of Conchology. Vol. XII, part 51, and 2nd Series, Vol. VI, part 27. 8° Philadelphia, 1892.

PERIODICALS, SERIALS, ETC.

Titles of Books. *Donors.*

American Journal of Science. Vol. XLIII, Nos. 256-257. 8° New Haven, 1892.
American Naturalist. Vol. XXVI, Nos. 301 and 303-305. 8° Philadelphia, 1892.
Annalen der Physik und Chemie. Neue Folge, Band XLV, heft 3-4; and XLVI, heft 1. 8° Leipzig, 1892.
Annales de Géologie et de Paléontologie. Liv. 10. 4° Palerme, 1892.
Annals and Magazine of Natural History. Vol. IX, Nos. 52-54. 8° London, 1892.
Athenæum. Nos. 3360-3372. 4° London, 1892.
Beiblätter zu den Annalen der Physik und Chemie. Band XVI, Nos. 2-4. 8° Leipzig, 1892.
Chemical News. Vol. LXV, Nos. 1686-1698. 8° London, 1892.
Colliery Guardian. Vol. LXIII, Nos. 1629-1641. Fol. London, 1892.
Geological Magazine. New Series, Decade III, Vol. IX, Nos. 2-6. 8° London, 1892.
Indian Engineering. Vol. XI, Nos. 14-26. Flsc. Calcutta, 1892.
PAT. DOYLE.
Iron. Vol. XXXIX, Nos. 1001-1013. Fol. London, 1892.
Mining Journal. Vol. LXII, Nos. 2951-2963. Fol. London, 1892.
Nature. Vol. XLV, No. 1168 to XLVI, No. 1180. 8° London, 1892.
Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Band I, heft 2; and Beliage-Band, VIII, heft 1. 8° Stuttgart, 1892.
Oil and Colourman's Journal. Vol. XIII, Nos. 141-142. 4° London, 1892.
Palæontographica. Band XXXVIII, lief 3-6, and XXXIX, lief 1. 8° Stuttgart, 1892.
Petermann's Geographischer Mittheilungen. Band XXXVIII, Nos. 3-5. 4° Gotha, 1892.
THE EDITOR.
Scientific American. Vol. LXVI, Nos. 10-22. Fol., New York, 1892.
" Supplement, Vol. XXXIII, Nos. 844-856. Fol., New York, 1892.
The Indian Engineer. Vol. XIII, Nos. 260-272. Flsc., Calcutta, 1892.
J. MACINTYRE.
Zoological Record. Vol. XXVII (1890). 8° London, 1892.

GOVERNMENT SELECTIONS, REPORTS, ETC.

BOMBAY.—Selections from the Records of the Bombay Government. New Series, Nos. 253 and 255. Flsc., Bombay, 1892. BOMBAY GOVERNMENT.
BURMA.—Twenty-fifth Annual Report on the Light Houses and Light Vessels off the Coast of Burma, for 1891-92. Flsc., Rangoon, 1892.
CHIEF COMMISSIONER, BURMA
INDIA.—Government of India Civil Budget Estimates for 1892-93. Flsc., Calcutta, 1892.
GOVERNMENT OF INDIA.
" List of Civil Officers holding gazetted appointments under the Government of India in the Home, Legislative, Foreign, and Revenue and Agricultural Departments, corrected to 1st January 1892. 8° Calcutta, 1892.
GOVERNMENT OF INDIA.
" Monthly Weather Review for August to October 1891. Flsc., Calcutta, 1892.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

Titles of Books. *Donors.*

INDIA.—Quarterly Indian Army List. New Series, No. 11. 8° Calcutta, 1892.
GOVERNMENT OF INDIA.

„ Register of Original Observations in 1891, reduced and corrected, August to October 1891. 4° Calcutta, 1892.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Selections from the Records of the Government of India in the Foreign Department. No. 287. Flsc., Calcutta, 1891.
FOREIGN DEPARTMENT.

TRANSACTIONS, PROCEEDINGS, ETC., OF SOCIETIES, SURVEYS, ETC.

ADELAIDE.—Transactions of the Royal Society of South Australia. Vol. XIV, pt. 2. 8° Adelaide, 1892. THE SOCIETY.

ALLAHABAD.—Minutes of the Managing Committee, Lucknow Provincial Museum, from April 1889 to March 1891. 8° Allahabad, 1892.
THE COMMITTEE, LUCKNOW MUSEUM.

BALLARAT.—Annual Report of the Ballarat School of Mines, Industries and Science, in the University of Melbourne, for the year 1891. 8° Ballarat, 1892.
THE SCHOOL OF MINES.

BALTIMORE.—Johns Hopkins University Circulars. Vol. XI, Nos. 96-97. 4° Baltimore, 1892. JOHNS HOPKINS UNIVERSITY.

BATAVIA.—Naturkundig Tijdschrift voor Nederlandsch-Indie. Deel LI. 8° Batavia, 1892. BATAVIAN SOCIETY.

„ Notulen van het Bataviaasch Genootschap van kunsten en Wetenschappen. Deel XXIX, Afl. 4. 8° Batavia, 1892. BATAVIAN SOCIETY.

„ Tijdschrift voor indische Taal-Land-en Volkenkunde. Deel XXXV, Afl. 2. 8° Batavia, 1892. BATAVIAN SOCIETY.

BELFAST.—Report and Proceedings of the Belfast Natural History and Philosophical Society for the Session 1890-91. 8° Belfast, 1892.
THE SOCIETY.

BERLIN.—Sitzungsberichte der Königlich Preussischen Akad. der Wissenschaftan. Nos. XLI to LIII; and Index. 8° Berlin, 1892. THE ACADEMY.

BOMBAY.—Journal of the Bombay Natural History Society. Vol. VI, No. 4. 8° Bombay, 1891. THE SOCIETY.

BRISBANE.—Annals of the Queensland Museum. No. 2. 8° Brisbane, 1892.
THE MUSEUM.

„ Proceedings and Transactions of the Queensland Branch of the Royal Geographical Society of Australia. Vol. VII, part 1. 8° Brisbane, 1892.
THE SOCIETY.

BUDAPEST.—Természetrajzi Füzetek. Vol. XV, Nos. 1-2. 8° Budapest, 1892.
THE HUNGARIAN NATIONAL MUSEUM.

BUFFALO.—Bulletin of the Buffalo Society of Nat. Sciences. Vol. V, No. 3. 8° Buffalo, 1891. THE SOCIETY.

CAEN.—Bulletin de la Société Linnéenne de Normandie. 4me Serie, Vol. V, fasc. 3-4. 8° Caen, 1892. THE SOCIETY.

CALCUTTA.—Epigraphia Indica of the Archæological Survey of India. Vol. II, part 9; and Index to Vol. I. 4° Calcutta, 1892. GOVERNMENT OF INDIA.

Titles of Books. *Donors.*

CALCUTTA.—Journal of the Asiatic Society of Bengal. Vol. LXI, part I, No. 1, and part II, No. 1; and Title page and Index to Vol. LX, part II, Nos. 1-4 of 1891. 8° Calcutta, 1892. THE SOCIETY.

" Proceedings of the Asiatic Society of Bengal. No. 3. 8° Calcutta, 1892. THE SOCIETY.

" Records of the Geological Survey of India. Vol. XXV, part 2. 8° Calcutta, 1892. GEOLOGICAL SURVEY OF INDIA.

" Report of the 14th Annual Meeting of the Indian Association for the Cultivation of Science, held in April 1891. 8° Calcutta, 1892. THE ASSOCIATION.

" Survey of India Department Notes for March to May 1892. Flsc. Calcutta, 1892. SURVEY OF INDIA DEPARTMENT.

CAMBRIDGE, *Mass.*—Bulletin of the Museum of Comparative Zoology. Vol. XXIII, No. I. 8° Cambridge, Mass., 1892. THE MUSEUM.

COLOMBO.—Journal of the Ceylon Branch of the Royal Asiatic Society. Vol. XI, No. 38. 8° Colombo, 1892.

DEHRA DUN.—Synopsis of the Results of the Operations of the Great Trigonometrical Survey of India. Vol. XXV. 4° Dehra Dun, 1891. GREAT TRIGONOMETRICAL SURVEY OF INDIA.

DRESDEN.—Sitzungsberichte und Abhandlungen der Naturwissenschaftlichen Gesellschaft Isis in Dresden. Jahrg. 1891, July to December. 8° Dresden, 1892. ISIS SOCIETY.

EDINBURGH.—Scottish Geographical Magazine. Vol. VIII, Nos. 4-6. 8° Edinburgh, 1892. SCOTTISH GEOGRAPHICAL SOCIETY.

" Transactions of the Edinburgh Geological Society. Vol. VI, pt. 3. 8° Edinburgh, 1892. THE SOCIETY.

HARRISBURG.—Geological Survey of Pennsylvania. Atlas, Southern Anthracite Field, part IV, A.A.; Atlas, Northern Anthracite Field, part VI, A. A.; Atlas, Western Middle Anthracite Field, part III, A. A. 8° Harrisburg, 1889. GEOLOGICAL SURVEY, PENNSYLVANIA.

" Report of Progress of the 2nd Geol.. Survey of Pennsylvania, F. 3. 8° Harrisburg, 1891. GEOLOGICAL SURVEY, PENNSYLVANIA.

LAUSANNE.—Bulletin de la Société Vaudoise des Sciences Naturelles. 3me Série, Vol. XXVII, No. 105. 8° Lausanne, 1892. THE SOCIETY.

LILLE.—Annales de la Société Géologique du Nord. Tome XIX. 8° Lille, 1892. THE SOCIETY.

LONDON.—Journal of the Chemical Society. Nos. 352-354. 8° London, 1892 F. R. MALLET.

" Journal of the Society of Arts. Vol. XL, Nos. 2052-2063. 8° London, 1892. THE SOCIETY.

" Mineralogical Magazine and Journal of the Mineralogical Society. Vol. IX, No. 44. 8° London, 1892.

" Proceedings of the Royal Geographical Society. New Series, Vol. XIV, Nos. 1 and 3. 8° London, 1892. THE SOCIETY.

" Proceedings of the Royal Society of London. Vol. L, Nos. 303 and 305. 8° London, 1892. THE SOCIETY.

" Proceedings of the Zoological Society of London. Part IV, and Index from 1881-1890. 8° London, 1892. THE SOCIETY.

" Transactions of the Zoological Society of London. Vol. XIII, part 4. 4° London, 1892. THE SOCIETY,

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LONDON.—Quarterly Journal of the Geological Society. Vol. XLVIII, No 190. 8° London, 1892. THE SOCIETY.

„ Report of the 61st Meeting of the British Association for the Advancement of Science, held at Cardiff in August 1891. 8° London, 1892.

LONDRES.—Congrès Géologique International. 4^{me} Session, 1888. 8° Londres, 1891.

MADRID.—Boletin de la Sociedad Geografica de Madrid. Tome XXXII, Nos 1-4. 8° Madrid, 1892. THE SOCIETY.

MANCHESTER.—Memoirs and Proceedings of the Manchester Literary and Philosophical Society. 4th Series, Vol. V, No. 1. 8° Manchester, 1891-1892. THE SOCIETY.

„ Transactions of the Manchester Geological Society. Vol. XXI, parts 14-17. 8° Manchester, 1892. THE SOCIETY.

MINNEAPOLIS.—Bulletin of the Minnesota Academy of Natural Sciences. Vol. III, No. 2. 8° Minneapolis, 1892. THE ACADEMY.

MONTREAL.—Annual Report of the Geological and Natural History Survey of Canada, for the year 1888-89. New Series, Vol. IV. 8° Montreal, 1890. GEOL. AND NAT. HIST. SURVEY, CANADA.

MOSCOW.—Bulletin de la Société Imperiale des Naturalistes. No. 4. 8° Moscow, 1892. THE SOCIETY.

NAPLES.—Atti della Reale Accademia delle Scienze Fisiche e Matematiche. Série 2, Vol. IV. 4° Napoli, 1891. THE ACADEMY.

NEWCASTLE-UPON-TYNE.—Transactions of the North of England Institute of Mining and Mechanical Engineers. Vol. XLI, part 1. 8° Newcastle-upon-Tyne, 1892. THE INSTITUTE.

PARIS.—Annales des Mines. 8^{me} Série, Tome XX, livr. 5 et 6, and 9^{me} Série, Tome I, livr. 2. 8° Paris, 1892. DEPARTMENT OF MINES, PARIS.

„ Annuaire Géologique Universel Revue de Géologie et Paleontologie. Tome. VII, fasc. 4 (1890). 8° Paris, 1892. THE EDITOR.

„ Bulletin de la Société Géologique de France. 3^{me} Série, Tome XIX, Nos. 9-11. 8° Paris, 1890-1891. THE SOCIETY.

„ Compte Rendu des Séances de la Société de Géographie. Nos. 5-8. 8°. Paris, 1892. THE SOCIETY.

PERTH.—Annual General Report of Western Australia for the years 1888-1890, by Harry Page Woodward, Govt. Geologist. 8° Perth, 1890-1891. THE AUTHOR.

„ Report on the Goldfields of the Kimberley District, Western Australia, by Harry Page Woodward, Govt. Geologist. 8° Perth, 1891. THE AUTHOR.

PHILADELPHIA.—Journal of the Franklin Institute. Vol. 133, Nos. 3-5. 8° Philadelphia, 1892. THE INSTITUTE.

„ Proceedings of the American Philosophical Society. Vol. XXIX, No 136; and List of Surviving Members on 9th January 1892. 8° Philadelphia, 1892. THE SOCIETY.

PISA.—Atti della Societa Toscana di Scienze Naturali. Mémorie. Vol. VI, fasc. 3. 8° Pisa, 1892. THE SOCIETY.

„ Atti della Societa Toscana di Scienze Naturali. Processi Verbali. Vol. VIII, pages 1-48. 8° Pisa, 1892. THE SOCIETY.

ROCHESTER.—Bulletin of the Geological Society of America. Vols. I and II. 8° Rochester, 1890-1891. THE SOCIETY.

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ROME.—Atti della Reale Accademia dei Lincei. Serie V, Rendiconti, Vol. I, fasc. 3-8. 8° Roma, 1892. THE ACADEMY.

„ R. Ufficio Geologico. Memorie descrittive della Carta Geologica d' Italia. Vol. VII. 8° Roma, 1892. GEOLOGICAL SURVEY OF ITALY.

ST. PETERSBURG.—Mémoires de L'Académie Impériale des Sciences de St. Petersbourg. Tome XXXVIII, Nos. 4-6. 4° St. Petersbourg, 1891. THE ACADEMY.

SINGAPORE.—Journal of the Straits Branch of the Royal Asiatic Society. No. 23. 8° Singapore, 1892. THE SOCIETY.

SYDNEY.—Journal and Proceedings of the Royal Society of New South Wales. Vol. XXV. 8° Sydney, 1892. THE SOCIETY.

„ Proceedings of the Linnean Society of New South Wales 2nd Series, Vol. VI, pt. 3. 8° Sydney, 1892. THE SOCIETY.

„ Australian Museum, Sydney. Catalogue of the Marine Shells of Australia and Tasmania. Part I, Cephalopoda. 8° Sydney, 1892. THE MUSEUM.

„ Records of the Australian Museum. Contents and Index to Vol. I; and Vol. II, No. 1. 8° Sydney, 1892. THE MUSEUM.

„ Records of the Geological Survey of New South Wales. Vol. II, part 4. 8° Sydney, 1892. THE SURVEY.

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MEMO.

The Geological Sketch Map of Sikkim, accompanying this issue, is referred to in Article 3, published in the Records of the Geological Survey of India, Volume XXIV, Part 4.

ERRATA.

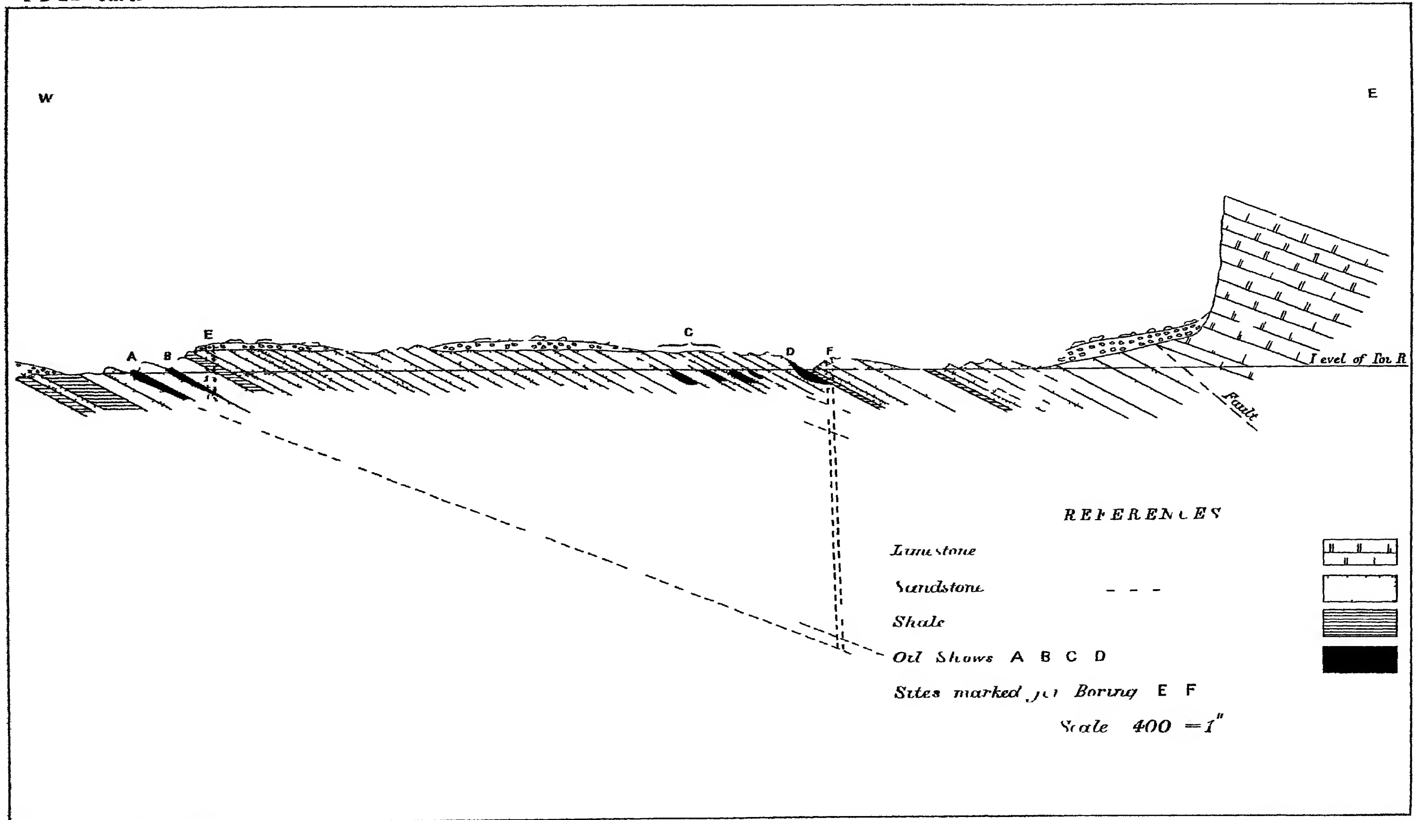
RECORDS, GEOLOGICAL SURVEY OF INDIA, Vol. XXV, pages 123-127.

Page.	Line.	For	Read
124-5-6	...	Langier	Laugier.
124	3 from bottom	Ile	I'lle.
125	24	Kantiamalée . . .	Kantiamal'é
125	5 from bottom	"I"	"J"
126	21	earths and sesquioxides .	earths sesquioxides.

ERRATA.

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA, VOL. XXV, PART 2

On page 61, line 19 from below, read: *skirting.*
„ „ 62, „ at bottom, read: *watershed.*
„ „ 63, „ 12 from below, instead of passs, read: *pass.*
„ „ „ „ 9 from below, insert a *comma* after Kábul province.
„ „ 65, „ 8 from below, for Mari, read: *Marine.*
„ „ „ „ 2 from below, for Baluchistán, read: *Sind.*
„ „ 68, „ 17 from above, for dislocation, read: *dislocations.*
„ „ 75, „ 17 from above, for Tangi Rájan, read: *Tangi Rojan.*
„ „ „ „ 22 from above, leave out the *comma* after: it may be.
„ „ „ „ 14 from below, for: Kóh-i-Sultán Áhméd Kabír, read: *Kóh-i-Sultán Ahmed Kabír.*
„ „ 80, „ 11 from above, for page 78, read: *page 69.*
„ „ 83, „ 2 from below, for nummulites, read: *nummulitics.*
„ „ 84, „ 11 from above, for no,, read: *not.*
„ „ „ „ 14 from above, insert *a* after them.
„ „ „ „ 17 from below, for most, read: *both.*
„ „ „ „ 13 from below, for predominate, read: *predominates.*
„ „ „ „ 11 from below, for page 83, read: *page 81.*
„ „ 86, „ 11 from below, for hence, read: *thence.*
„ „ „ „ 8 from below, for Khank, read: *Khanki.*
„ „ 87, „ 14 from above, for sapposition, read: *supposition.*
„ „ 89, „ 7 from below, leave out: *lower.*
„ „ 92, „ 8 from above, for: of the existence, read: *on the supposed existence.*
„ „ „ „ 26 from above, for Kam Silmán, read: *Kam Shilmán.*
„ „ 95, „ 14 from below, omit the *comma* after road.
„ „ 97, leave out the second foot-note at bottom of the page.
„ „ 103, „ 12 from above, leave out: *of.*
„ „ „ „ 14 from above, from *north-west to south-east.*
„ „ 105, „ 16 from above, for dislocation, read: *dislocations.*
„ „ „ „ 18 from above, for palæozoic, read *palæozoics.*
„ „ 10?, „ 16 from above for certainly, read: *certainty.*



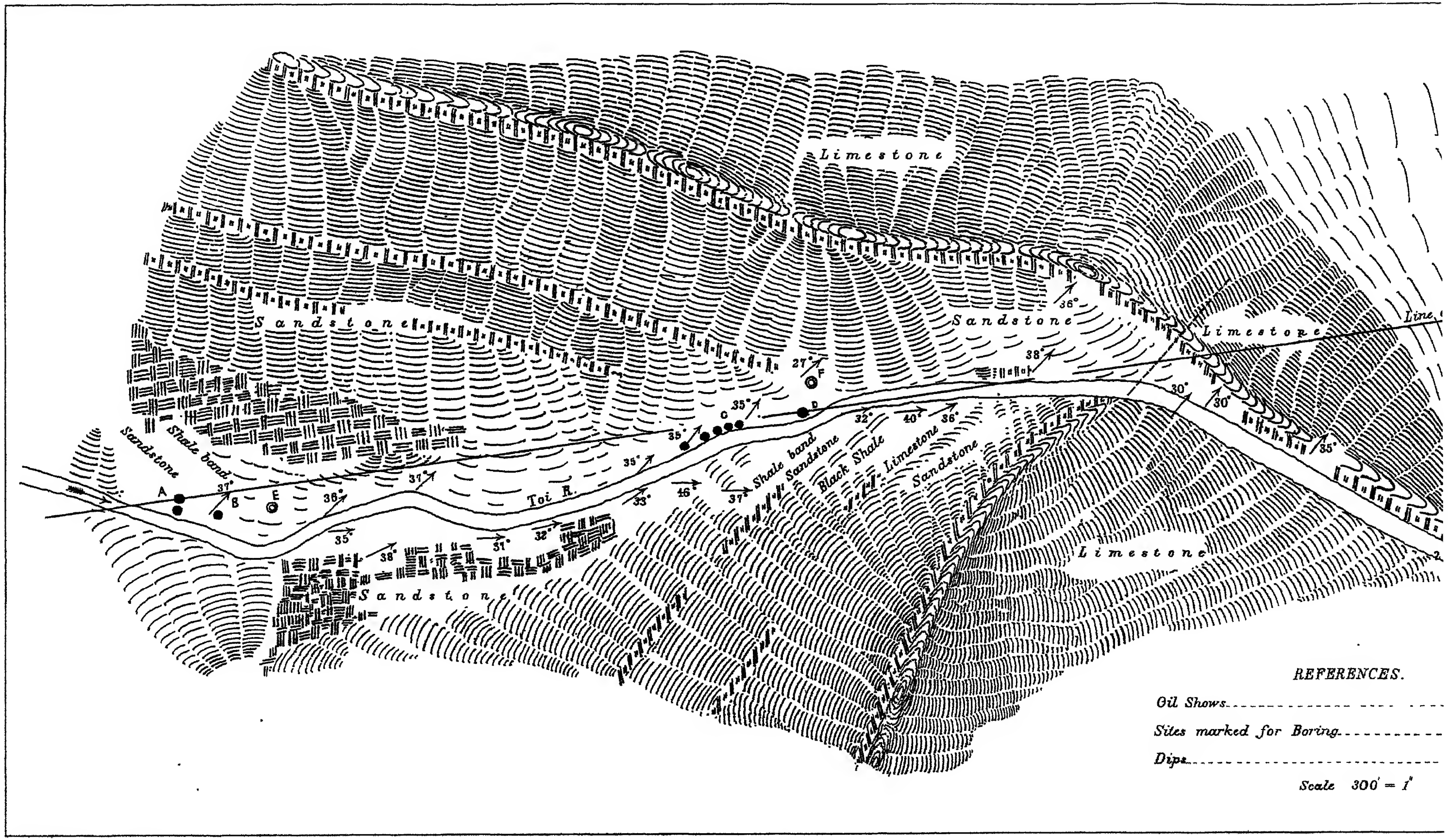
Lithographed & Printed at

Geological Survey Office

SECTION through the TIRI CHUAKHEL
on the line A–D (see Plan)

T. D. La Touche.

GEOLOGICAL SURVEY OF INDIA.



Lithographed & Printed at

PLAN of the TIRI CHUAKHEL near MOGHAL KOT, SHIRANI HILLS. Showing the position of the OIL SHOWS.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1892. [Nov.

Report *on the* Oil Springs *at* Moghal Kot *in the* Shirani Hills, *by* Tom D. LaTouche, B.A., *Deputy Superintendent, Geological Survey of India* (With 2 plates.)

Introductory remarks.

The oil springs in the vicinity of Moghal Kot, a village in the Shirani Hills lying about 12 miles to the south-east of the Takht-i-Suleiman, appear to have first been brought to notice about the end of the year 1889, when samples of the oil, purporting to be from this locality, were sent down to Calcutta and examined both in the laboratory of the Geological Survey and by Dr. Warden, Chemical Examiner to the Bengal Government. The first sample examined by Dr. Warden was, according to his conclusions, "not a crude, but a commercial kerosine oil of Russian origin." Subsequently, Dr. Warden reported on a sample, procured by the Deputy Commissioner of Dera Ismail Khan from this locality, which he found to be of excellent quality. Another specimeen collected by Mr. Oldham in 1891 and examined in the laboratory of the Geological Survey by Mr. Holland, although inferior in quality to the sample examined by Dr. Warden, was found to contain large quantities of liquid hydrocarbons.[1] The doubts attending the stated existence of the oil, if not of its quality, having been removed, it remained to discover what the chances were of its being procurable in sufficient quantites to render it commercially valuable, a question which Mr. Oldham was unable to decide, owing to the hurried manner in which he was compelled by ill-health to carry out his observations. This, therefore, is the point I have mainly kept in view during my recent exploration of the country.

Position of the springs.

About a mile above the village of Moghal Kot, the river Toi[2] traverses a lofty ridge, running north and south, the greater portion of which is composed of hard fine-grained quartzose sandstones, overlaid by a thick band of massive limestone. Through these rocks the river has cut a deep narrow gorge, about half a mile in length; the oil springs are found in this

[1] *Records, Geol. Surv.* Vol, XXIV, pt. 2, page 86.

[2] This river is erroneously called the Cholkhel Dhana in the map of 1884; *Dhana* is the name locally given to the gorges cut by the streams through the Takht-i-Suleiman range, and does not apply to the whole of the river valley. The minor gorges through the belts of hard rock beneath the main range are called *Tiri*, as Tiri Chuakhel, Tiri Khidarzai, etc., while those through the outer belt of hard rocks at the edge of the hills are called *Zam*, as Zam Chandwan, Zam Draband, etc.

gorge, and their position is indicated in the plan of it annexed to this report. The most copious discharge takes place close to the base of the quartzose sandstone (at the points marked A and B on the plan), but oil also oozes from them at the points C and D, about midway between the base and summit. In all cases the discharge takes place close to the water's edge. At C the rocks are merely saturated with the oil, and at D it occurs in the form of small globules, floating on the water collecting in shallow holes in the shingle on the river bank. The flow was so slight at these points that no good samples of the oil could be collected for examination. At A and B, however, the oil gathers in shallow holes dug in the sand at the level of the water in the river, and from these spots I obtained good samples which have been sent down to Calcutta to be examined in the laboratory of the Geological Survey. The actual points of outflow seem to have been determined by the existence of beds of shale intercalated with the sandstones; the oil apparently creeping up along the bedding planes, beneath these shale bands until it reaches the surface.

Quality of the oil.

As it issues from the rock the oil is limpid, slightly yellow in colour and opalescent. It has an unmistakable odour of kerosine, which can be perceived at several paces from the spots where it escapes from the rock; and without any refining whatever it gives a brilliant light when burnt in an ordinary lamp. The sample obtained from A seemed to me to be rather more oily in character than that from B, and I at first thought that the difference between the sample examined by Dr. Warden and that collected by Mr. Oldham might have been due to their having been collected from these different spots, but Mr. Holland has since informed me that the samples from A and B are essentially the same, the slight difference being accounted for by an exposure of the sample from A for a short while.

No gas observed.

No traces of gas were observed to accompany the discharge of oil at any of the spots where it issues from the ground.

Rate of discharge of the oil.

The rate of discharge of the oil is exceedingly slow. I had one of the shallow holes in the sand at each of the points A and B cleaned out, and the time occupied in filling a quart bottle with the oil was observed. Making a rough calculation from this I find that one of the holes at A would yield a gallon of oil in $4\frac{1}{2}$ hours, while it would take 14 hours to collect the same amount at B. The discharge might possibly be increased to a slight extent by clearing away the sand, but it was impracticable for me to test this, as it would have entailed the construction of a dam to keep out the river water. Under the most favourable circumstances I do not think that the flow would exceed 10 gallons a day from both these places.

Occurrence of oil extremely local, no traces of it found in extension of the sandstone band to the north.

The ridge of hard rocks in which the oil of Moghal Kot occurs extends for about 30 miles to the north of the Toi river, and is traversed by other streams, the principal being the Shingao, which breaks through it above the village of Karam; the southern branch of the Lohara, or Drazund river, breaking through the ridge immediately beneath the Takht-i-Suleiman itself at Raghasur; and the northern branch of the same river, which flows round the north end of the Takht, through the gorge called the "Gut," and issues at Powa Sur, a small village above Murgu. In each of these cases the section exposed is identical with that in the

gorge of the Toi, yet in neither of them did I succeed in detecting the slightest trace of oil. Its occurrence therefore in appreciable quantity is extremely local, and the band of sandstone in which it occurs cannot be considered as in any sense a generally oil-bearing stratum, that is, a stratum in which we should be likely to find an accumulation of oil at any point, even though the conditions at that point were otherwise favourable.

Peculiar structure of rocks in Tiri Chuakhel facilitating escape of oil.

It is true that the escape of the oil in the gorge above Moghal Kot is facilitated by the peculiar structure of the rocks in that locality. Along the line of the river-bed there is a decided twist in the strike of the rocks, the beds to the south of it dipping east or within a few degrees of east, while on the north bank the dip is steadily north-east. The effect of this twist, combined with the dip of the rocks, from 30 to 40 degrees has been to form a kind of inverted trough, rather steeply inclined to the east, along the axis of which the flow of oil has been concentrated. This structure, however, although it would account for a larger outflow at this point than at any other if the sandstones were everywhere oil-bearing, will not account for the entire absence of oil at the other points where the ridge is cut through. The conclusion I have drawn is that there is no real connection between the peculiar structure of the rocks and the occurrence of the oil at this particular locality, that it is, in fact, a mere coincidence.

Before discussing the question as to whether there are any places in the Shirani Hills where an accumulation of oil may have been formed sufficiently near the surface to be reached by borings of a reasonable depth it will be well to set forth briefly the general considerations, underlying the problem.

General conditions under which accumulations of oil in workable quantities are formed.

Although the conditions under which petroleum is originally formed by natural processes in the bosom of the earth are not yet fully understood none of the theories that have been from time to time put forward to account for its production, whether by distillation from coal seams or other organic matter, or by chemical combination in one form or another, being entirely satisfactory, yet in determining the probability of its occurrence in large quantities in any locality where it is known to exist we are not concerned with any of these theories, for it is fairly certain that the oil is seldom or never indigenous in the strata from which it is obtained by borings, but that it has been introduced into them by percolation from regions far below, so deeply seated that they have never been, nor are likely to be, reached by borings from the surface. We have therefore only to deal with the conditions under which the oil may collect at various points in porous strata, in such a manner that it is stored as in a reservoir, until a way is opened for its escape to the surface by borings or otherwise. Such conditions, it seems to be now universally admitted, are most favourable where the strata are thrown into gentler undulations, anticlinals and synclinals, so disposed that the oil rising from below is held under the crowns of the anticlinals, presupposing that the porous strata which afford storage for the oil are covered by impervious beds, which prevent its rising further towards the surface. Conditions so favourable as these are, however, realised in few cases, the oilfields of Pennsylvania, Baku, and Burma being the most notable instances; at the same time accumulations of oil in workable quantities are not unknown in localities where the strata are more highly disturbed, *e. g.*, in Galicia; but in such places the means of escape naturally afforded to the oil are easier than in the oilfields abovementioned, and therefore, although the surface indications may be even more

conspicuous than they are in those fields, the accumulations of oil are never so great. A full discussion of the conditions under which oil is worked in such disturbed regions, with special reference to those generally obtaining in India, will be found in Mr. Medlicott's "Note on the occurrence of Petroleum in India,"[1] where sections are given showing the disposition of the strata in the highly disturbed oil-bearing regions of Galicia.[2]

Conditions found to exist in the Shirani Hills.

Such being the considerations to be kept in view when estimating the probabilities of oil occurring in any district known to be oil-bearing, in sufficient quantities to be profitably worked, it remained to be seen to what extent they would apply in the Shirani Hills. In determining this point we have only the outcrops of the rocks overlying the oil-bearing rocks to guide us, and the evidence afforded by these is, I regret to say, distinctly unfavourable. In passing down the Toi river from the oil-springs we obtain a very clear section of these rocks. The group of hard quartzose sandstones, about 1,000 feet thick, in which the oil occurs, is overlaid by a band of hard massive limestone, about 300 feet thick, the whole dipping in an easterly direction at between 30 and 40 degrees. Following on the limestone, and dipping in the same direction, with some minor folds, a great series of shales with sandstone bands of various thickness is found. The total thickness of this group is probably not less than 10,000 feet and the strata composing it are inclined to the horizon at about the same angle as the limestone beneath. Above this group comes a series of beds containing gypsum bands at the base, overlaid by bands of nummulitic limestone and fossiliferous shales. These also have an easterly dip though not so high as in the beds beneath, as far as Parwara village, below which there is a well-marked synclinal. On the eastern side of this the beds are repeated, dipping west, as far as the horizon of the gypsum bands, which are exposed in the hill on which Domanda outpost stands. Here there is a sharply compressed anticlinal fold, upon the denuded edges of which sandstones of Siwalik age have been deposited. This is the anticlinal noticed by Mr. Oldham in his "Preliminary report on the oil locality near Moghal Kot"[3] under which he suggests "there is probably a considerable accumulation of oil." The lowest beds exposed, however, on the crest of the anticlinal are the shales immediately underlying the gypsum bands, which, as we have seen, are the topmost members of a group of rocks 10,000 feet thick. It would in all probability therefore be necessary to bore through the whole thickness of that group, and 300 feet or so of hard limestone beneath, before reaching the sandstones in which oil might possibly occur. It need hardly be said that such an undertaking would be utterly absurd. Moreover this anticlinal is not an open undulation, like those beneath which the most productive oil-bearing strata are found; indeed, it bears evidence of so much crushing, that it would be difficult to account for the non-existence of any oil shows along its crest, supposing that the rocks beneath did contain oil. To the north of the Toi this anticlinal has been traced as far as the Lohara or Drazand river presenting everywhere the same features. Thus, although it offers the nearest approach among these hills to the conditions found to be favourable in other oil-producing regions, yet

(1) *Records, Geological Survey*, Vol. XIX, pt. 4, p. 185.

(2) See also a paper by Mr. R. D. Oldham, "Memorandum on the mode of occurrence of Petroleum," published in 1891.

3 *Records, Geological Survey*, Vol. XXIV, pt. 2, p. 84.

these conditions are so far different as to render it unprofitable to undertake operations on so large a scale as would be necessary to determine the existence of oil along that line.

Possibility of increasing the present outflow by means of wells or borings.

Such being the case it remains to be considered whether it would not be possible to increase the discharge of oil in the neighbourhood of the present springs by means of wells or borings. A well might be sunk at the point E on the plan, which would meet the beds, from which the oil at A and B issues at a depth of about 130 feet. Short galleries, driven in either direction along the strike of the beds from the bottom of this well, would afford a more ready means of escape for the oil than now exists, and such a plan would have the advantage of excluding the water from the river, which under present conditions filters in through the sand covering the outcrop, and becomes mixed with the oil. But I doubt whether the outflow would be increased to any material extent by such means, for the oil at so slight a depth would not be under much greater pressure than at the surface.

Another plan might be tried, though it would doubtless be more expensive, and that is to sink a deep boring through the whole of the strata known to be oil-bearing, that is from a point to the east of D on the plan, say at F.[1] Such a boring would have to be at least 760 feet deep in order to reach the lowest oil beds, and should be of large diameter, say 6 inches. I do not anticipate much difficulty in boring such a hole through the sandstones, as in all probability they are much softer in the interior than at the surface. On reaching the lowest oil beds, unless the flow of oil under the increased pressure was found to be satisfactory, a powerful charge of dynamite, or "torpedo," should be exploded at the bottom of the hole, so as to shatter the rock in its vicinity. This might possibly largely increase the flow of oil and the experiment might be worth trying at least. The difficulty would be to get the machinery required for boring a hole of such a size to the spot. There is an unlimited supply of water power, which might be made use of instead of steam, as the river at this point has a considerable fall (about 50 feet measured from the head of the gorge), and even at the time of my visit, in March 1892, after twelve months of practically rainless weather, there was a sufficient volume of water in it for all purposes. Every part of the machinery would have to be brought on camels from the edge of the hills, a distance of about 25 miles, as the only way of reaching the place is along the stony bed of the Toi river, where it would be impossible to use wheeled vehicles.

Second Note *on* Mineral Oil *from the* Suleiman Hills, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India.*

Last year (1891) I published an account of a chemical examination of crude mineral oil collected by Mr. R. D. Oldham above Moghal Kot in the Suleiman Hills, Sheráni country.[2] From the comparatively high specific gravity and flashing

[1] The two points E and F were chosen so that they lie above flood-level. They are marked on the ground by stone cairns.

[2] "On Mineral Oil from the Suleiman Hills." *Records, Geological Survey of India,* Vol. XXIV (1891), pp 84–97.

point, and from the results of fractional distillation, indicating a predominance of the heavier hydrocarbons, I concluded that, compared with other samples previously obtained from the same district, the specimen sent by Mr. Oldham must be considered to be decidedly inferior in quality. Mr. T. H. D. LaTouche has recently sent two samples collected by himself at the same locality (one and a half miles above Moghal Kot, Sheráni country), and a chemical examination of these samples proves them to be extremely valuable for illuminating purposes, thus confirming the result obtained by Dr. Warden in September 1890, and at the same time explaining, as will be pointed out below, the apparent inferiority of Mr. Oldham's specimen.

The following is the result of an examination of the two samples collected near Moghal Kot by Mr. La Touche :—

Specimen A.

This sample was a deep yellow, mobile liquid, slightly turbid through the presence of disseminated bituminous particles, and with a large quantity of water at the bottom of each bottle. Cleared of its dirt the oil showed a well-marked fluorescence and possessed a slightly aromatic odour. The specific gravity at 60° Fahr. was 0·819.

The flashing point, determined by Sir Frederick Abel's apparatus, was 75° Fahr.

A measured quantity of the oil was subjected to fractional distillation with the following results:—

Temperature of Distillation.	Distillate.			
	Sp. Gr. at F.	Colour.	Per cent. by volume.	Per cent. by weight.
1st fraction distilling between 140° and 340° F.	0·753	Colourless	10	9·19
2nd " " " 340° " 360° "	0·770	"	10	9·39
3rd " " " 360° " 373° "	0·781	"	10	9·53
4th " " " 373° " 427° "	0·795	"	10	9·70
5th " " " 427° " 460° "	0·812	"	10	9·91
6th " " " 460° " 482° "	0·823	"	10	10·05
7th " " " 482° " 521° "	0·834	Faint yellow tinge.	10	10·18
8th " " " 521° " 563° "	0·849	Pale yellow.	10	10·36
9th " " " 563° " 594° "	0·861	Rich straw-yellow.	10	10·51
10th " " " 594° and above .	...	Yellow .	...	6·84
Residue: paraffin "scale" and "coke" . .	...	...	...	3·94
Loss	...	...	...	0·40
Total .	...	...	...	100·00

The first three fractions flashed below 73° Fahr.; the remainder at higher temperatures. The ninth fraction, which was very mobile at the temperature of the laboratory (91° Fahr.), commenced to thicken appreciably on being cooled to 38° Fahr. and solidified at 27° Fahr. It will be noticed that the first nine fractions distilled over below 594°, showing that the heavier solid hydrocarbons are not present in large proportions. Of the remaining tenth, a part (6·84 per cent. by weight of the *original* quantity) consisted of a yellow oily liquid, which became of the consistence of *ghee* on cooling to 70° Fahr., on account of the solidification of the heavier paraffins. The remainder partially solidified in the condenser and partially remained in the retort. I did not consider it necessary to "coke" the portion left in the retort, as an estimation of the carbonaceous residue apart from the paraffin 'scale' would, in the present instance, offer very little information of use in forming an estimate of the economic value of the oil. The same remark applies also to the sample B., whose characters are described below, and in which also the solid hydrocarbons exist in very small quantities.

In estimating the proportion of *illuminating oil* I mixed 10 cubic centimetres of each of the first nine fractions, the mixture possessing a specific gravity of 0·808 at 60° Fahr. and flashing at 72° Fahr. After treatment with sulphuric acid, and subsequently with caustic soda to remove the impurities, a current of air was passed through the oil, whilst the flask was immersed in a warm water bath, to remove the very volatile naphthas introduced with the first fraction. The residue, which was almost "water white" and possessed a slight fluorescence, gave a flashing point of 76° Fahr. and a specific gravity of 0·810 at 60°. The removal of the naphthas, to raise the mixture to the legal limit of safety, was attended with a loss of 2·5 cubic centimetres. The burning oil of good quality may thus be set down at 87·5 per cent by volume (86·5 per cent. by weight) of the crude material.

The water accompanying this sample contained lime in solution with traces of iron and magnesia, and in combination with sulphuric, carbonic, and hydrochloric acids. It was neutral to litmus test.

Specimen B.

A clear, rich, straw-coloured liquid with a strongly marked fluorescence and slightly aromatic smell. Specific gravity at 60° Fahr.: 0·811. Flashing point (Abel's test): 64° Fahr.

Fractional distillation of 300 cubic centimetres gave the following results :—

Temperature of Distillation.	Distillate.			
	Sp. Gr at 60 F.	Colour.	Per cent by volume.	Per cent by weight.
1st fraction distilling between 145° and 317° F.	0·741	...	10	9·13
2nd " " " 317° " 330° "	0·757	...	10	9·33
3rd " " " 330° " 382° "	0·777	...	10	9·58
4th " " " 382° " 424° "	0·793	...	10	9·77
Carried over .				

Temperature of Distillation.	Distillate.			
	Sp. Gr. at 60 F.	Colour.	Per cent by volume.	Per cent by weight.
Brought forward .	...	..	...	...
5th fraction distilling between 424° and 448° F.	0·806	...	10	9·95
6th " " " 448° " 488° "	0·822	...	10	10·14
7th " " " 488° " 507° "	0·836	...	10	10·32
8th " " " 507° " 567° "	0·851	...	10	10·49
9th " " " 567° and above	0·864	...	10	10·65
10th Above 567° F.	...	...	...	2·75
Residue: paraffin "scale" and "coke" . .	...	...	...	6·14
Loss	...	...	..	1·75
TOTAL .	..	...	...	100·00

In this specimen the temperature reached 600° Fahr. before the 9th fraction had completely distilled, and of the remainder 2·75 per cent. (of the *original* quantity) distilled over as a yellow, oily liquid which solidified on cooling to 55° Fahr. The remainder solidified at the temperature of the laboratory (90° F.)

To determine the proportion of illuminating oil 10 cubiccentimetres of each of the first nine fractions were mixed, the most volatile naphthas removed in the usual manner, and the residue purified with strong sulphuric acid and caustic soda. The product, measuring 84 cubic centimetres was a "water white" oil of specific gravity 0·810, flashing at 85° Fahr. The proportion of illuminating oil is thus 84 per cent. by *volume* (83·9 per cent. by weight). This result is perhaps slightly within the limit of production, as the removal of the naphthas was overdone by after-manipulation of the mixture at the high temperature of the laboratory (91° F.): the flashing point is thus raised well above the legal minimum and the specific gravity slightly above average American, but below some Russian kerosenes.

In comparing these two specimens it will be seen that *B* contains slightly large proportions of the very volatile hydrocarbons as well as the heavier and solid paraffins, whilst in *A* there is a greater predominance of the liquid compounds of intermediate density, which are of value for illuminating purposes. There is, therefore, a slightly greater waste in preparing *B* for the market, as the excess of very volatile compounds must be removed to bring the flashing point up to the legal minimum (73° F.) and the solid compounds must be eliminated to obtain a freely burning oil. Both samples are, however, of very high value, and there is no doubt that should they occur in sufficient quantity no foreign oil could compete against them.

These oils are evidently of the same kind as the sample examined by

Dr. C. J. H. Warden in September 1890, and in which he estimated a yield of at least 90 per cent. of very superior, nearly "water white," illuminating oil.

In the following table the results obtained by Dr. Warden are compared with these which I have now obtained from Mr. LaTouche's specimens :—

Fractional distillation of Moghal Kot petroleums.

	I	II	
		A	B
1st fraction, 10 per cent.	·7557	·753	·741
2nd " "	·7685	·770	·757
3rd " "	·7802	·781	·777
4th " "	·7948	·795	·793
5th " "	·8077	·812	·806
6th " "	·8204	·823	·822
7th " "	·8367	·834	·836
8th " "	·8487	·849	·851
9th " "	·8596	·861	·864

I.—Procured by the Deputy Commissioner, Dera Ismail Khan, and examined by Dr. C. J. H. Warden (1890).

II.—Collected by Mr. T. H. D. LaTouche and examined by T. H. Holland (1892).

Referring now to the results of my examination of the Moghal Kot petroleum collected by Mr. Oldham,[1] it will be seen that in that specimen, whilst the liquid hydrocarbons predominate the very volatile constituents are absent. The first tenth obtained in the fractional distillation is seen to have a specific gravity of ·0782 whilst of the original crude material the flashing point was 128° Fahr. and specific gravity (at 60° F) 0 831—all of which results are much higher than those obtained from the two specimens whose analyses I now report, and also of the specimen examined by Dr. Warden.

I find also that the remainder of Mr. Oldham's sample, which I have kept in the laboratory, is deeper in colour than either of those sent by Mr. LaTouche. From a comparison of the figures I should say that an oil like the former might easily be obtained from specimen A. (of LaTouche) by simple exposure to the open air in a warm climate, and this conclusion I find to be confirmed by artificially imitating the necessary conditions. I passed a current of air through 500 cubic centimetres of specimen A for twenty-four hours at a temperature varying within a few degrees of 90° F., and on examining the residue I found the flashing point had risen from 75° to 132° Fahr., and the density had increased from 0·819 to 0·835, whilst it had lost 14 per cent. of its original volume. On subjecting this residue

[1] *Records, Geological Survey of India,* Vol. XXIV (1891), p. 84.

to fractional distillation I obtained a series of distillates which agree very closely with those obtained from Mr. Oldham's sample, as will be seen by the following table :—

	Specific Gravity of Distillates.	
	I.	II.
1st fraction of 10 per cent	·782	·784
2nd " " "	·794	·794
3rd " " "	·803	·803
4th " " "	·813	·812
5th " " "	·823	·820
6th " " "	·835	·829
7th " " "	·847	·845
8th " " "	·857	·856
9th " " "	·869	·868

I.—*Sp. Gr.:* 0·831. *Flashing point:* 128° Fahr. Collected by Mr. R. D. Oldham (1891), *Records, Geological Survey of India*, Vol. XXIV., pp. 84 and 85.

II.—*Sp Gr.:* 0·835. *Flashing point:* 132° Fahr. Residue after removal of naphthas from Specimen A, collected by Mr. T. H. D. LaTouche in the same locality.

These results show that artificial removal of the very volatile hydrocarbons from Mr LaTouche's Sample *A* leaves a residue resembling in every respect the specimen previously collected by Mr. Oldham.

On a New, Fossil, Amber-like Resin *occurring in* Burma, *by* Dr. Otto Helm, *of* Danzig. (*Translated by* Thomas H. Holland, *Geological Survey of India.*)

Dr. Fritz Noetling, under orders of the Director of the Geological Survey of India, has sent me a piece of amber-like resin from Upper Burma. I have, as far as the small quantity of material would permit, made a chemical and physical examination of the specimen, and I hope to follow the publication of this preliminary investigation with a further contribution.

The fragment under examination is covered with a thin weathered crust of a brown colour. When broken it exhibits a shining, conchoidal fracture, with a greasy touch. The internal colour is dark-yellow, some parts being transparent and others sub-transparent, the latter being beclouded with organic matter finely disseminated through the substance of the resin. The specimen exhibits a fine blue

fluorescence. If light be sent into the interior with a convex glass lens, the cone of light appears of a golden yellow colour. In polarised light the same colour is exhibited, changing however, by revolution of the Nicols through 90°, to blue and orange.

The resin is as easy to cut, saw, and polish as the Baltic amber (Succinite); it is a little harder, however, than the latter, its hardness varying between 2·5 and 3.

Its specific gravity is 1.034.

As to the chemical constituents of this fossil resin I am not yet able to give an ultimate analysis, as the piece in my possession exhibits no portion of perfectly clear colour, but is clouded throughout by finely disseminated particles. I have, nevertheless, made a dry distillation of the resin, and the results are extraordinarily interesting and different from those which other fossil resins give under like conditions. During the distillation, for which I used a glass retort, there first appeared a white vapour-cloud, which, on cooling, condensed to water-white drops; subsequently the vapour became tinged with yellow and condensed in thin oily streaks; ultimately the cloud was dissipated and thick oily drops flowed into the receiver. The distillate is a brownish yellow oil, with tarry consistency, of a peculiar burnt smell and an extremely small quantity of a watery liquid. I treated this liquid with hot water and filtered: it was water-white and gave an acid reaction with litmus-paper. On repeated distillation over a steam-bath a liquid distilled over and a yellowish residue remained behind, which I cleaned by solution in water with subsequent filtration and evaporation. The small quantity of crystals thus obtained I recognised, by well-known chemical reactions, to be pyrogallic acid, whilst the aqueous distillate contained formic acid. Succinic acid was not found in the products of distillation.

The resin contained 0·6 per cent. of ash, which was composed of iron-oxide, sulphuric acid, carbonic acid, and lime. I found a very small quantity (0·013 per cent.) of sulphur in combination with organic substances.

The fusion point of the resin cannot be determined, as before that point is reached it decomposes with evolution of a white aromatic vapour.

The resin proved to be very resistent against solvents:— Chloroform dissolves only 2·2 per cent. of it. Alcohol dissolves 0.8 per cent., the solution leaving behind, on drying, a black-brown resin. Ether dissolves 2.4 per cent., the solution leaving, on evaporation, a clear yellow resin. By oil of turpentine 18.5 per cent. was dissolved, whilst carbon bisulphide dissolved 4.6 per cent.

If the pulverised material is treated with concentrated sulphuric acid, the resin gradually dissolves, forming a solution of a red-brown colour, which blackens on heating. When the red-brown solution is treated with water a dirty white deposit separates out. Concentrated nitric acid at the ordinary temperature has little effect on the resin, but on heating the latter is changed into a yellow friable substance.

By friction the resin becomes electric and retains its electricity for some time.

From the foregoing investigation it seems that the Burmese resin differs from all the fossil resins with which I am up to the present acquainted; and I shall continue this research as soon as further specimens of clear colour are available.

Preliminary notice *on the* Triassic Deposits *of the* Salt Range.—By W. WAAGEN, PH.D., F.G.S.

For some years now I have been occupied with the study of the fossils that have been collected in the Salt-Range by different members of the Geological Survey staff, amongst them myself, as having found the greater part of those specimens that are characteristic of the higher divisions of the triassic strata of that country.

Though it is against my general custom to give a preliminary notice of the results of my investigations before the larger publication in the Palæontologia Indica can be ready for printing, in this case I feel obliged to do so on account of further explorations on a great scale which are now going on in the Himalaya, and which have for their object strata about equivalent to those that I have had the good luck to explore in the Salt-Range. It seems to me to be directly my duty to give to those indefatigable explorers in the Himalayas the benefit of my experiences in the Salt-Range, in order that they may be able to compare the Himalayan development of the Trias with that exposed in the Salt-Range.

The triassic strata of the Salt-Range were distinguished by Mr. Wynne under the general name of the Ceratite Beds—a name extremely appropriate for them—as nearly all the fossils contained in these strata consist of the remains of ammonoid shells all showing a "Ceratitic" development of their sutural lines. As regards the fossil forms that have been collected up to the present from these strata I must state that my studies have as yet been restricted chiefly to the Cephalopoda; and that amongst these only the "*Trachyostraca*" have been examined in detail. Thus I am only able to give their exact indications.

The Ceratite beds, as is shown in the first volume of my "Salt-Range Fossils," rest directly and without distinct unconformity on the topmost beds of the Productus Limestone, and are covered at their upper limit by the "Variegated Series" of Wynne. It must be remarked that the Ceratite beds do not comprehend all the strata that we in Europe generally comprise under the name of "Triassic Formation"; but that the Rhaetics are yet included in the Variegated Series, as they cannot be distinguished there from the Liassic Series, so that the top beds of the Ceratite strata cannot be more recent than "Carnic" at the utmost.

The lowest division of the Ceratite beds is formed by the "lower Ceratite Limestones: thinly bedded, light grey limestones, very hard, that loudly ring under the hammer. The fossils are mostly exposed on the bedding planes, and can be detached only with difficulty. Nearly all the Cephalopoda that occur in these strata belong to the genus *Gyronites* n. gen. W., a genus that has formerly been united by me wrongly with *Xenodiscus*, but which is distinct from that genus by a short body chamber, whilst *Xenodiscus* possesses a long one. *Gyronites* is most nearly related to *Meekoceras*. Besides *Gyronites* there are but very few other genera, and these represented only by single species. Of the *Trachyostraca* there is a single species of *Dinarites* present.

The next higher division is composed of the "Ceratite Marls." These are greenish-grey crumbling marls, with limestone concretions in which the fossils are contained. Small beds of limestone show a cone-in-cone structure. The Cephalopod fauna is perfectly different from that of the next lower division. The genus *Proptychites* n. g. (*Prop. lawrencianus*, Kon. sp.) predominates, *Gyronites* has

become much rarer, whilst *Meekoceras* increases enormously in numbers. Also here the *Trachyostraca* are represented by a single species of *Dinarites*.

Above the marls follows a thick series of yellow sandstones. These sandstones contain to all appearances three different faunas of Cephalopoda.

In the lower division of these sandstones there occur besides many species of *Meekoceras* and other allied genera of the *Leiostraca*, a number of typical forms of the *Trachyostraca*, *Dinarites* 2 sp., *Ceratites* 1 typical species, *Prionites* n. gen. (nearly allied to *Ceratites*, but the auxiliary lobes dissolved in very numerous small denticulations) 1 sp., *Celtite* 1 sp.

In the middle division a small gasteropod of the genus *Stachella* is very numerous, and therefore I have called these beds "Stachella beds." Here also many peculiar species of Cephalopoda occur, chiefly *Meekoceras* and allied genera. The genus *Flemingites* n gen. makes here its first appearance, whilst the *Trachyostraca* are only represented by the genera *Dinarites* and *Celtites*.

In the upper division the fauna is not very rich but very characteristic. The genus *Flemingites* (*Flem. flemingianus* Kon. sp.) furnishes the most predominant forms. For this reason I have called these beds "Flemingites beds." *Meekoceras* and *Gyronites* are yet numerously represented; the genus *Proptychites* has got here its last representant.

Of the *Trachyostraca* the genera *Dinarites*, *Ceratites*, *Prionites*, and *Celtites* have been found, each of them, however, only represented by a single species. Besides these the first representant of the genus *Acrochordiceras* has been detected in these beds. The development of this form is, however, a very strange one, as the second lateral lobe is quite imperfect, and not distinctly developed. According to its sculpture this shell can, however, not be determined otherwise than as *Acrochordiceras*.

Above the Ceratite Sandstones a quite new fauna commences, and it can therefore, I think, not be much doubted that with these sandstones a greater period in the earth's history comes to a close. Thus probably the lower Trias must be terminated here, and all the beds that have been mentioned by me up to this horizon must be considered as the equivalents of the "Bunter Sandstone" of Europe. In Europe Cephalopoda are very rare in the Bunter, and only in the Alps there exists a bed in which the remains of Cephalopoda have more numerously been found. This represents probably the topmost division of the Bunter Sandstone only, whilst the lower divisions are all devoid of Cephalopoda shells. In India now there are not less less than five different faunas of Cephalopoda in the Bunter, and these commence already in the very lowest divisions of that formation so that apparently by the description of the Salt-Range faunas of the Bunt Sandstone a great gap in our knowledge of the triassic faunas will be filled up.

The division that follows next above the sandstones is composed again of limestones, and has received by me the name of "Upper Ceratite limestones." This division had been included by me in 1889 in the "Grey Bivalve limestones." The Cephalopod fauna contained in these Ceratite limestones is the richest one of all the triassic beds of the Salt-Range. Besides many species of *Leiostraca*, which have not yet been studied in detail, but which all appear to be more or less nearly related to *Meekoceras*, there are numerous forms of *Trachyostraca*, which are of the utmost interest, but of which no species is identical with a European one. Of the genus *Dinarites* there is only a single species, which has received by me the name of

Din. dimorphus W., and which exhibits so many points of affinity to *Din. glacialis* Mojs. from Siberia, that I cannot but consider the two as belonging to one and the same group of forms. Of the genus *Ceratites* there are not less than seven species, three of which belong to the "*Circumplicati*," two to the "*Nodosi*," one to the "*Subrobusti*," and one to the "*Nudi*." The new genus *Prionites* W. is represented by three species, and the genus *Balatonites* by one, somewhat doubtful form.

Of the family *Tropitidæ* the genus *Celtites* has furnished not less than eight species, which can be divided in two groups. One of them has got more squarish whorls, and resembles in this respect somewhat the group of *Celtites floriani*, Mojs.; the other has got more oval or roundish whorls, and thus resembles somewhat the group of *Celtites epolensis*, Mojs. The genus *Acrochordiceras* occurs in these limestones in typical forms and has furnished four species. Very nearly related to *Acrochordiceras*, but yet sufficiently distinct by the existence of enormous lateral thorns and a smooth external side, is a new genus, for which I intend to introduce the name of *Stephanites* W., and of which two species have been found.

A very remarkable fact relating to this fauna is also the frequent occurrence of the genus *Sibirites*, of which there are at least ten species. They are typically more or less nearly related to the forms described by Mojsisovics from Siberia.

This Cephalopod fauna, just described, is the last one that occurs in the triassic beds of the Salt-Range. Higher up only single stray specimens of Cephalopoda shells have been found.

The division that follows next higher in the sequence of strata is a series of hard grey limestones crowded with the remains of bivalve shells. I have therefore called these beds "Bivalve limestones." Of Cephalopoda there have been found in these beds some species of *Gyronites*, of *Meekoceras*, and a single form of *Dinarites*, besides some very characteristic species of *Nautilus*, which very much resemble European triassic shells. The same is the case with many of the bivalves, of which some *Myophoriæ* and *Gervilliæ* look as if collected in the German Muschelkalk.

I am inclined to consider the Upper Ceratite limestones as well as the Bivalve limestones as the equivalents of the Muschelkalk of Europe. So much is certain that with the latter again a great division comes to a close, and that the beds which follow yet higher in the series belong to another system of rocks.

The next higher division is composed of dolomitic strata which often show a rather indistinct bedding and attain a very considerable thickness. I have called these beds the "Dolomitic Group." This group of rocks is nearly devoid of organic remains. Some small internal casts of barely determinable bivalves and gasteropoda were the only fossils that I was able to detect. They are hardly sufficient to determine independently the age of these strata.

At last there follows above the Dolomitic group a small set of thinly bedded yellowish limestones, exposed in the west mostly, just at the base of the "Variegated Group." I shall introduce for them the designation of "Topmost limestones." They are crowded with fossils, chiefly bivalve shells, but also some Cephalopoda among them. The fossils can, however, only with the utmost difficulty be detached from the rock; and only a single species is in a fit condition to be deter-

mined exactly, but this is of very great interest. It is an ammonoid Cephalopoda shell, which on a first glance might be determined by everybody as a species of *Tropites*, but on a closer examination one finds that the sutural lines, as far as they can be observed, are much simpler than in the mentioned genus. There is only a single lateral lobe present, and this is only with very small denticulations: no ramifications whatever as in *Tropites* proper. Therefore, I must consider this form as belonging to a new genus, for which I shall introduce the name of *Pseudharpoceras*. Nevertheless it is of great interest to find here a form so nearly related to the genus *Tropites*, a genus which is so very characteristic of the Upper Trias of Europe.

I thus am led to parallelise the Dolomitic group as well as the topmost limestones with the Upper Trias (Keuper) of Europe That in this Upper Trias the Rhaetic beds are not included has been remarked already above. They seem to be represented by a part of the Variegated series, as in some beds of this division species of plants, which occur also in the Rajmahal-beds, have been found.

It has been shown in former publications, that an overlap takes place at the base of the Variegated series, and thus the upper limit of the Ceratite formation is very distinctly marked. The formation must be terminated by the topmost limestones as distinguished by me. Whether then by the beds exposed in the Salt-Range the entire series of the upper triassic strata up to the Carnic group is represented, or whether there exists a greater gap, correspondig in time to the overlap, cannot be stated now.

The most peculiar feature then that results from all that has been stated up to the present consists in the circumstance that all the ammonoid Cephalopoda shells that have been found in the triassic beds of the Salt-Range show ceratitic, very rarely goniatitic, sutural lines, whilst the ammonitic development is completely absent. This constitutes a fundamental difference from nearly all the other triassic countries I had to describe already from the Permian of the Salt-Range a number of perfectly ammonitic forms, and in the next succeeding strata all such have absolutely disappeared.

In the Himalayas we have numbers of ammonitic forms in triassic beds, such as *Ptychites* and the like genera, but these are out of strata, which in their age most probably correspond to the Muschelkalk of Europe. In lower positions the Cephalopod fauna seems, according to Mr. Griesbach's indications, to be rather similar to that of the Salt-Range. It will now be one of the most important questions that will have to be solved by the exploration of the Himalaya, to state how far up in the series of strata the similarity to the Salt-Range extends, and in what relation the *Ptychites*-bearing rocks are to those containing part of the Salt-Range Ceratite fauna. Then also the question as to the definitive parallelisation of the Salt-Range strata with those of Europe can be borne out, and it will be possible to demonstrate whether my view, that the Upper Ceratite limestone must be considered as equivalent to part of the Muschelkalk of Europe, be correct or not.

If this view should prove to be correct this would go far to show conclusively that the Salt-Range triassic deposits belong to a triassic zoological province, which bears a certain similarity to the one that has been described in its contents from Siberia, but which would be absolutely different from that as developed in the Himalaya and the Alps.

ADDENDUM.

In connection with the preceding paper by Dr. W. Waagen I have thought it advisable to add the following translation of a paper read by Dr. Mojsisovics at the Academy of Sciences, Vienna, in May last, in which also the learned author gives a clear account of the origin and aim of the recent joint expendition which was sent to the Central Himalaya for the further collection of fossils from the Triassics between Milam and Niti. This Mission has now returned wtih a splendid and fully representative series of fossils, which are being dispatched to Vienna for study and description by our very highly esteemed and most specially versed Austrian *confrères* in Alpine Triassic geology, for whose engagement too on this work we have to thank a very constant and warm friend of the Survey, Professor Ed. Suess. Half of the collection will ultimately be returned to the Survey Museum. *Ed.*

Preliminary Remarks *on the* Cephalopoda *of the* Himalayan Trias.—By DR. EDM VON. MOJSISOVICS.[1]

At the suggestion of C. L. Griesbach, who for some years past worked as Geologist on the Geological Survey of India, and who as such has earned much distinction by his travels and studies in the Himálaya and in Afghánistán, the Geological Survey of India consented to send the entire palæontological collections of the various Himálaya expeditions to Professor Ed. Suess in Vienna, with the request that this material might be described and worked out by Austrian specialists.

Invited by Professor Suess, I agreed to undertake the description of the Cephalopoda of the Trias, whilst Dr. Alex. Bittner will look after the description of the remaining fossils of this formation.

By far the larger portion of the Cephalopods of this collection bolongs to the lower beds of the Trias (concerning which we possess papers by Salter, Blanford, Stoliczka, Oppel, and Griesbach), and these demonstrate that in the Himálaya the Muschelkalk is represented by a fauna analagous to that of the Alpine Muschelkalk, whilst the Buntsandstein has yielded a peculiar fauna of its own.

However, almost completely unknown up to now were Cephalopods from the upper division of the Trias; they are represented in this collection by a few small suites of specimens found by Griesbach, which specimens are, however, of the greatest interest. It is unfortunate that the material is, quantitatively speaking, quite insufficient, if one is not contented with merely establishing the fact of the existence of a few species, but wishes to obtain a deeper insight into the composition of the different faunas and of the zoo-geographical relations of the latter to the arctic-pacific Trias province on the one hand, and to the European faunas of the triassic period on the other. For these reasons I declared, immediately after the receipt of the collections, that the material is insufficient for a monographic description of the Trias Cephalopods of the Himálaya, and I expressed at the same time the wish that, considering the great scientific interest which a more detailed knowledge of Himálayan Trias would possess, a special expedition might be organized and despatched for the purpose of making extensive collections at the more importan and promising localities.

[1] Sitzungsbericht d. Kais. Akademie d. Wissenschaften, Vienna. Math. Nat. Classe; Vol. CI, Abth. I, May 1892.

Thanks to the liberal response of the Director of the Geological Survey, who obtained for the purpose the necessary funds from the Indian Government, and owing to the liberality of our Academy, which voted a considerable sum of money out of the Boué fund; this expedition has now been made possible, and to Dr. C. Diener, who is in every respect fit to solve the task, has been entrusted the mission. Before this expedition leaves, it seems to me useful to set down our present knowledge of the subject, by giving a short sketch of the triassic cephalopods of the Himálayas as far as the available material permits, and by the aid of the stratigraphic data furnished by Griesbach.

I.—The alleged youngest cephalopod horizon represents approximately the zone of *Tropites subbullatus* of our Hallstatt limestones. The fauna consists chiefly of *Tropites* species, and shows quite a wonderful analogy with the forms of the Salzkammergut. The ammonites are unfortunately not very well preserved in the marly grey limestones, which impedes somewhat the determination and comparison of the same. The locality is situated close to the frontier of Tibet, seemingly in a stratigraphically very disturbed region.

Griesbach looked upon this horizon as lower lias according to the labels attached to his specimens, without, however, mentioning this fact in his fine volume on the "Geology of the Central Himálayas.[1]" I presume that the seeming similarity of the keeled *Tropites* species with *Arietites* has caused this mistake.[2]

Lower Lias is mentioned as occurring in normal position over rhaetic strata at other localities, the latter beds certainly agreeing in development with the Koessen beds of the Alps. It would be of the greatest importance to ascertain whether the *Tropites* limestone of Kalapani corresponds stratigraphically really with this Lower Lias, or, as may be more probable, it belongs to a lower horizon. In the first case, we would not be entitled to identify in future the complex of beds which lies below the *Tropites* beds with the rhaetic formation of Europe.

II.—A second Upper Trias Cephalopod horizon is found, according to Griesbach's report, below the Lower Rhaetic, which is correlated with our Dachsteinkalk and Hauptdolomite. At Rimkin Paiar were found a few small ammonites of the genera *Sibirites*, *Heraclites* and *Halorites*, which are related to forms in the Juvavian Hallstatt limestones; for which reason this fauna is of specially great interest, and it is most desirable to obtain further collections from this locality.

III.—A third cephalopod horizon of Upper triassic type is found at the base of Griesbach's Upper Trias, and is connected with dark *Daonella* limestone also of Upper Triassic type. The few specimens which we have out of this horizon belong to the genera *Arcestes*, *Entomoceras*, *Arpadites* and (?) *Trachyceras*.[3] Several of them remind me of species which occur in our Alps in the zone of *Tropites subbulatus*.

IV.—Whilst the Upper Triassic cephalopods here mentioned are known at present only from the regions of the Central Himalayas near the Tibetan frontier, it appears that the next horizon possesses a much wider horizontal distribution, for it is found not only in Kumaun, Niti, and the adjoining regions of Tibet, but occurs also

[1] Mem. Geol. Surv. Ind., Vol. XXIII.

[2] The label was written in the field, when the specimen was mistaken for Arietites, but the locality was later on recognized as Trias, and so recorded on the map. *Ed.*

[3] From this horizon seem to be derived a small portion of the fossils from the Niti Pass described by Salter in the "Palæontology of Niti."

in the second Triassic province of the Central Himalayas, that of Spiti, which is already known for some considerable time.

From this horizon, which may be looked upon as a homotaxial equivalent of the European Muschelkalk, are derived the fine series of fossils, collected by the Brothers Von Schlagintweit and described by Oppel, which are preserved in the Palaeontological Museum at Munich; also the fossil remains from Spiti described by Stoliczka, and part of the forms figured by Salter and Blanford in the "Palaeontology of Niti" which are now in the British Museum in London.

The collection entrusted to me for description comprises the entire material from this horizon, which was contained in the Calcutta Museum, including all the figured types of Stoliczka. This suite of fossils is far inferior to the Schlagintweit collection in the Munich Museum, but contains a few very valuable and interesting specimens.

Palaeontologically considered, the Muschelkalk of the Himalaya forms a connecting link between the "Arctic" and the "Mediterranean" Muschelkalk development, and I have already proposed for it the term "Indian Trias-Province." [1]

It should be prominently noted that a few genera occur in the Indian Muschelkalk which are only known in Upper Triassic strata in Europe.

Amongst them are—

Sagenites,	with the	species	*S. medleyanus* (Stol.)
Isculites,	"	"	*I. hauerinus* (Stol.)
Lobites,	"	"	*L. oldhamianus* (Stol.)
Cladiscites,	"	"	*Cl. indicus* (*Amm. gaytani*, Stol.)

V.—As the merit of the discovery of these three Upper Triassic Cephalopod horizons belongs to the indefatigable Griesbach, so also do we entirely owe our knowledge of the following cephalopod fauna, which underlie the Muschelkalk, to his investigations.

Within the upper division of a great thickness of beds immediately underlying the Muschelkalk, south-east of Muth in Spiti, a series of grey "Wellenkalk" like beds occur which contain a great number of casts of large ammonites, which remind one strongly of the great cephalopod fauna of the ceratite beds of the Salt Range, which W. Waagen is now describing.

Only, however, when further additions to this collection have been made, and Waagen's material has been worked out, will it be possible to decide whether this correlation is correct. Dr. Waagen looks upon the fauna of the ceratite beds of the Salt-Range as proving the latter to be homotaxially equivalent to the European Buntsandstein.[2]

VI.—At the base of the same series of beds are the *Otoceras* beds, discovered and exploited by Griesbach, with a cephalopod fauna of few genera, but great abundance of individuals. It is a true shell-limestone, chiefly formed of *Xenodiscus* specimens. Much rarer are *Meekoceras*, *Otoceras* and *Prosphingites*.[3]

In a somewhat lighter-coloured, less argillaceous rock, both in Spiti and in

[1] Arktische Trias faunen, Mém. de l'Académie imp. des sciences de St. Petersbourg. VII. Serie, T. XXXIII, No. 6, p. 153.

[2] I have before me a lower triassic fauna from the Bay of Ussuri near Vladivostock in Eastern Siberia, which has been absolutely unknown till now. I believe it to be homotaxially of Buntsandstein age. Muschelkalk also occurs there (Russkj Island) developed similarly to the Spitzbergen Trias, characterized by specimens of *Ptychites* and *Monophyllites*.

[3] Several species derived from this horizon, amongst them *Otoceras woodwardi*, have been described and figured by Griesbach in Rec. Geol. Surv. Ind, Vol. XIII, pp. 94 to 113.

Kumaun, occur forms which differ slightly from the species which are found in the typical Otoceras beds, and these possibly belong to a horizon which may be distinguishable from the lowest beds. Amongst the fossils of this upper horizon very evolute ceratites are conspicuous, which probably belong to the genus *Dinarites* although they remind one strongly of *Tirolites*. It appears that these beds are of great horizontal distribution, since several specimens of *Dinarites* in the collection have been brought from Banda in Kashmir.

As regards the probable age of these beds, which are immediately underlaid by Permian strata with *Producti*, it may be remarked here that the fossil contents bear the zoological character of a low Buntsandstein fauna. Goniatites are completely absent, and the ceratitic development of lobes prevails entirely. For this reason, the fauna appears still younger than the Permian species described by Abich from the Araxes defile near Julfa in Armenia, which contains besides *Goniatites*, also some species of *Otoceras*, although the latter are not so highly developed as the forms in the Indian Otoceras beds. It is therefore most probable that the Indian Otoceras beds form the base of the Buntsandstein, and are closest to the boundary of the Permian.

Since we also relegate the cephalopod fauna, mentioned in paragraph V, to the Buntsandstein ; it appears that the richest series of the Buntsandstein hitherto known is found within the Himalayan area : and that whilst in Europe and in Siberia the cephalopod-bearing beds begin far higher up, namely, immediately below the Muschelkalk[1]), in the Himalayas the entire series of strata of limestones and shales of homotaxially Buntsandstein age, shows a genuine pelagic character, and sediments, rich in cephalopods are found already at the base of the same.

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No. 13.—ENDING 31ST OCTOBER 1892.

Director's Office, Calcutta, 31st October 1892.

The Director returned from privilege leave on the 24th of September. During his absence, Mr. Hughes, who officiated for him, spent most of the time on duty at Simla in immediate conference with the Revenue and Agricultural Department

[1] This is proved in the case of the Siberian Olenek beds by the high state of development of the principal cephalopod species.

The Diener Expedition, instituted by the Academy of Sciences of Vienna in communication with the Government of India, for the collection of a fuller and more representative series of fossils from the Triassic formation, as displayed in the Himalayan frontier country between Milam and Niti on the one side and the Thibet-Hundes on the other, has been brought to a successful conclusion. The party consisting of Dr. Diener who had been sent out from Vienna, and Messrs. Griesbach and Middlemiss of this Survey, broke up in the middle of October. Dr. Diener leaves Calcutta for Vienna on the 3rd November: a large collection of fossils which is fully and very duplicatively illustrative not only of the features and relations of the questions arising out of the more poorly represented series in the collections sent to Europe by the Survey last year for determination and description by Austrian specialists, follows Dr. Diener. A very happy result of the Mission is that the original survey of this Himalayan region by Mr. Griesbach has received complete confirmation. The further fossil evidence which was required to completely establish his three upper Triassic Cephalopod zones, and more especially his Indian Muschelkalk horizon, with *Sagenites*, etc., and those of the *Dinarites* and the *Octoceras* beds, attributed to lower Triassic age, are reported to have been fully supplemented.

In the South of India, Mr. Holland took the opportunity, during the last month, of following up the series of ultra-basic rocks which he discovered last season in the Salem district. In the north-west direction, they occur intruding into the metamorphics of the Mysore State, and in places are accompanied by a development of magnesite and chalcedonic veins similar to those exposed on the well-known "Chalk" hills. The Corundum beds of the Hunsur taluq, which are associated with graphitic schists and are frequently interrupted by the above-mentioned igneous rocks, follow the general north-north-west and south-south-east strike of the crystalline schists of that area, and they may be traced from Singanamaranhalli in the south-east to Ramenhalli in the north-west; whilst, from the evidence of specimens which have been collected, it seems that the same beds extend in one direction into the Coimbatore district and in the opposite direction to the Uppinagadi taluq of the South Canara district—coinciding thus with the general direction of foliation of the metamorphic rocks. Amany of these rocks are of considerable petrologica interest, Mr. Holland is preparing an account of their microscopic characters to accompany his field-notes. Amongst them we find a large series of hypersthene-bearing rocks varying in composition from hypersthene-microcline-granite to almost pure hypersthene-rocks. Various stages, also, in the decomposition of the Corundum, with its silicification and hydration, are represented amongst the specimens collected.

In a previous issue of these tri-monthly notes, No. 11, ending 30th April last, it was mentioned that Dr. Noetling had been successful in unearthing a series of vertebrate fossils from the tertiary rocks near Yenangyoung. This collection is now being registered in the Museum of the Survey, and it turns out to be one of the finest displays of Siwalik forms which has been brought to light since the historic finds of Cautley and Falconer in the original Siwalik area. So far, Dr. Noetling has been able to discriminate the following:— ? *Squaledon, sp.*, ? *Lutia, sp.*, *Anthracotherium silistrense*, Pent., *Anthracotherium*, cf. *hypotamoides*, Lyd., *Cervus, sp.*, *Bubalus platyceros*, Lyd., *Boselaphus, sp.*, *Hipparion antelopinum*, Fal. and Caut., *Sus titan*, Lyd., *Hippopotamus iravadicus*, Lyd., *Rhinoceros* (*Acerotherium*) *iravadi-*

cus, Lyd., *Rhino. sivalensis*, Fal. and Caut., *Elephas* (*Stegodon*) *clifti*, Fal. and Caut , *Mastodon latidens*, Clift. *Avis, sp. nov.*, *Colossochelys atlas*, F. and C., *Emyda sivalensis*, Lyd., *Trionyx, sp.*, *Crocodilus sivalensis*, Lyd., *Garialis, cf. gangeticus*, Gmel., *Myliobates, sp.*, *Lamna, sp.*, *Cartharias, sp.*

Chipped flints were found in the *Hipparion antelopinum* bed, together with *Rhino. iravadicus*, *Rhino. sivalensis*, *Garialis gangeticus*, *Crocodilus*, sp., *Colossochelys atlas* and *Trionyx, sp.*

The officers of the Surey have been disposed for the camping season as below, and most of them are now at the scene of their operations :—

Rewa.—Theo. W. H. Hughes, Superintendent ; F. H. Smith, Assistant Superintendent ; Kishen Singh, Sub-Assistant.

Baluchistan —C. L. Griesbach, C.I.E., Superintendent.

Assam.—R. D. Oldham, Superintendent.

Lower Burma.—P. N. Bose, Deputy Superintendent ; P. N. Datta, Assistant Superintendent.

Upper Burma.—Fritz Nöetling, Palæontologist.

Salt-Range Coal.—Tom. D. LaTouche, Deputy Superintendent ; W. B. D. Edwards, Assistant Superintendent.

Hazara.—C. S. Middlemiss, Deputy Superintendent ; Hira Lal, Sub-Assistant.

Head-quarters.—The Director ; and T. H. Holland, Assistant Superintendent.

It is intended that Mr. Hughes shall visit Mergui early next year, in view of the coal exploitation on the great Tenassarim river, which is about to be undertaken by Mr. Bose. Mr. Oldham, at present on leave, will keep touch with head-quarters until the forthcoming Manual of the Geology of India is completely passed for Press. Mr. Holland is engaged, in addition to his other duties, in lecturing on Geology at the Presidency College. He will avail himself of every opportunity for continuing his mineral exploration in the Madras Presidency.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October, 1892.

Substance.	For whom.	Result.
Two specimens of ferruginous quartz, from Mysore mines assayed for gold.	T. W. H. HUGHES, Geological Survey of India.	

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October, 1892—continued.

<table>
<tr><th>Substance.</th><th>For whom.</th><th colspan="4">Result.</th></tr>
<tr><td rowspan="9">Three specimens of coal, and one of iron pyrites, from Burma.</td><td rowspan="9">P. N. DATTA, Geological Survey of India.</td><td></td><td>"Outcrop, ½ miles east by south of Pakhaung Village." Quantity received, 17¼ oz.</td><td>"Chaumojoo stream, seam (b)." Quantity received. 12 oz.</td><td>"Chaumojoo stream, seam (c)." Quantity received. 27 oz.</td></tr>
<tr><td>Moisture . . .</td><td>8·40</td><td>6·20</td><td>7·10</td></tr>
<tr><td>Volatile matter . . .</td><td>34·40</td><td>38·54</td><td>34·02</td></tr>
<tr><td>Fixed carbon . . .</td><td>49·52</td><td>47·70</td><td>40·82</td></tr>
<tr><td>Ash . . . .</td><td>7·68</td><td>7·56</td><td>18·00</td></tr>
<tr><td></td><td>100·00</td><td>100·00</td><td>100·00</td></tr>
<tr><td></td><td>Does not cake.</td><td>Does not cake.</td><td>Does not cake.</td></tr>
<tr><td></td><td>Ash, reddish brown.</td><td>Ash, reddish grey.</td><td>Ash, reddish grey.</td></tr>
<tr><td colspan="4">Nodular iron pyrites, from Sagaing District, Burma. Quantity received 9¼ oz. Contains 29·6 per cent. of sulphur.</td></tr>
<tr><td>Four specimens of Amalgam</td><td>J. DRIVER, Managing Agent, Kalianpur-Behar Gold Mining Co., Ld., Calcutta.</td><td colspan="4">Assayed for gold and silver.</td></tr>
<tr><td>Four specimens; quartz, clay, etc., for gold; and 6 specimens for tin, from Burma.</td><td>P. N. BOSE, Geological Survey of India.</td><td colspan="4">(1) Quartz, from "Oleingwin, old pits."
(2) Quartz, stained with oxide of iron from "Shwe Dong, near Tavoy."
(3) Quartzite, with specks of iron pyrites, from "Manoroon."
(4) Ferruginous clay, from "Shwe Dong, near Tavoy."
} Contain no gold.</td></tr>
</table>

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October, 1892—continued.

Substance.	For whom.	Result.
		(1) Washed sand, chiefly tourmaline, from "Frathan, head-waters of the Lenya River." Contains tin. (2) Washed sand, from "Manoroon." Contains a trace of tin. (3) Washed sand, from "Shwe Chang Myetta." Contains tin. (4) Decomposed granite, from "Granite Hill Mines, Inner Bokpyn." Contains no tin. (5) Red micaceous sandstone, from "Hill Mines, Maliwoon." Contains no tin. (6) Specimen from "near Indeorza." =Wolframite, with quartz.
Coal found while digging a well at Village Chattri, about 42 miles from Bikanir, at a depth of about 240 feet from the surface; seam about 5 feet thick.	C. S. Bayley, c.s., Political Agent, Bikanir.	*Quantity received 12¾ oz.* Moisture . . . 9·04 Volatile matter . . 30·30 Fixed carbon . . 14·42 Ash . . . . 46·24 100·00 Does not cake. Ash-pale gray.
Quartz and calc-spar, with iron pyrites, from Chota Nagpur.	J. Yates, Mackillican & Co, Bengal Gold and Silver Mining Co., Calcutta.	Assayed for gold.
Two specimens of rocks, from Madras, for silica percentage.	Thomas H. Holland, Geological Survey of India.	*No. I, 470, from N. W. of Kanjamalai, 1 mile from Sitheswarankovil.* Contains 54·46 per cent. silica (SiO_2). *No.* $\frac{8}{754}$, *from Pallavaram.* Contains 47·79 per cent. silica (SiO_2).
Amber, from the amber mines, Upper Burma.	F. Nöetling, Geological Survey of India.	No. I, 359, sp. gr. 1·037. " I, 362, " 1·046. " I, 363, " 1·039. " I, 366, " 1·036. " I, 367, " 1·033. " I, 367, " 1·037. " I, 367, " 1·035. " I, 367, " 1·035. " I, 370, " 1·042. " I, 371, " 1·036. " I, 371, " 1·037.
Coal and clay, from Kalaba Toung, about 12 miles from Kyaukphyu.	A. Leids, Deputy Commissioner, Kyaukphyu.	*Coal. Quantity received, 66lbs.* Moisture . . 3·02 Volatile matter . 53·12 Fixed carbon . 29·34 Ash . . . 14·52 100·00 Cakes strongly. Ash, red.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1892 –concluded

Substance.	For whom.	Result.
Crystalline limestone, found in Sikkim.	J. C. WHITE, Political Agent, Sikkim.	*Clay. Quantity received, 7lbs.* Fused completely at a reddish-white heat; will not answer as a fire-clay. Contains 21·00 per cent. of insoluble matter, consisting of sand, etc., the rest (79 per cent.) being carbonate of lime, with a trace of iron and alumina.

Notifications by the Government of India and the Geological Survey of India during the months of August, September, and October 1892, published in the ' Gazette of India," *Parts I and II.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Revenue and Agricultural Department.	$\frac{1639}{106}$, dated 3rd August 1892.	P. N. DATTA, Assistant Superintendent, Geological Survey.	Privilege	26th Aug. 1892.	18th Oct. 1892.	
Ditto .	$\frac{1779}{174}$, dated 16th August 1892.	H. B. W. GARRICK, Artist, Geological Survey.	Do. .	20th Aug. 1892.	10th Oct 1892.	
Geological Survey Depertment.	1205, dated 26th August 1892.	R. D. OLDHAM, Superintendent, Geological Survey.	Do. .	7th Oct. 1892.	...	

Annual Increments to graded Officers sanctioned by the Government of India during August, September, and October 1892.

Name of officer.	From	To	With effect from	No. and date of sanction.	REMARKS.
P N. DATTA, Assistant Superintendent, Geological Survey.	*R* 300	*R a. p.* 313 5 4	1st July 1892.	Revenue and Agricultural Department No. $\frac{1612}{161}$, dated 30th July 1892.	

Annual Increments to graded Officers sanctioned by the Government of India during August, September, and October 1892—concluded.

Name of officer.	From	To	With effect from	No. and date of sanction.	REMARKS.
	R	R a p.			
F. H. SMITH, Assistant Superintendent, Geological Survey.	350	380 0 0	1st August 1892.	Revenue and Agricultural Department No. $\frac{1737}{172}$, dated 13th August 1892	
T. H. HOLLAND, Assistant Superintendent, Geological Survey.	380	410 0 0	1st September 1892.	Revenue and Agricultural Department No. $\frac{2040}{155}$, dated 13th September 1892.	
C. L. GRIESBACH, Superintendent, Geological Survey.	900	950 0 0	1st August 1892.	Revenue and Agricultural Department No. $\frac{2051}{184}$, dated 13th September 1892.	
FRITZ NÖETLING, Palœontologist, Geological Survey.	660	700 0 0	1st October 1892.	Revenue and Agricultural Department No. $\frac{2335}{202}$, dated 22nd October 1892.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. HUGHES . . .	Mirzapur	Mirzapur.
C. L. GRIESBACH . . .	Quetta	Quetta.
R. D. OLDHAM	Calcutta	Calcutta.
P. N. BOSE	Mergui	Tavoy.
T. H. D. LATOUCHE . . .	Haranpur . . .	Haranpur.
C. S. MIDDLEMISS . . .	Abbottabad . . .	Abbottabad.
W. B. D. EDWARDS . . .	Haranpur . .	Haranpur.
P. N. DATTA	Mergui	Tavoy.
F. NÖETLING . . .	Calcutta	Calcutta.
HIRA LAL	Abbottabad . . .	Abbottabad.
KISHEN SINGH	Mirzapur . . .	Mirzapur.

DONATIONS TO THE MUSEUM.

FROM 1ST AUGUST TO 31ST OCTOBER 1892.

A miscellaneous collection of minerals, from Cornwall.

PRESENTED BY CHARLES VON DER HILLEN, 53, CHOWRINGHEE, CALCUTTA.

A specimen of auriferous quartz, from the Rajgeer Range, about 4 miles from the eastern end, Behar; and a string of beads made from rock crystals, at Nana, about 8 miles south of Behar.

PRESENTED BY C. PURDY, KALYANPUR.

Fragment of a molar of Elephas sp., from the Godavari River.

PRESENTED BY T. VANSTAVERN, DOWLAISHWERAM.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1892.

Titles of Books. *Donors.*

ANDRÉ, *George G.*—A Practical Treatise on Coal-mining. Vols. I and II. 4° London, 1888.

BALL, *Sir Robert.*—The Cause of an Ice Age. 8° London, 1891.

BECKER, *George F.*—Geology of the Quicksilver Deposits of the Pacific Slope. 4° Washington, 1888.

REVENUE AND AGRICULTURAL DEPARTMENT.

BENEDIKT, *Dr. R.*, and KNECHT, *E.*—The Chemistry of the Coal-Tar Colours. 8° London, 1889.

BLAKE, *J. F.*—Annals of British Geology for 1890. 8° London, 1891.

BONNEY, *Prof. T. G.*—The Year-Book of Science for 1891. 8° London, 1892.

BREZINA, *Aristides.*—Explanation of the principles of Crystallography and Crystallo-physics. 8° P. Washington, 1874.

BRONN'S Klassen und Ordnungen des Thier-Reichs:—

Band II, Abth. II., lief. 6-8.
„ II, „ III., „ 13-16.
„ III, lief. 1.
„ IV, „ 21-23.
„ V, Abth. II., lief. 32-34.
„ VI, „ V, „ 37-39.

8° Leipzig, 1892.

CASSINO, *S. E.*—The Scientists' International Directory, containing the names, addresses, special departments of study, and of Professional and Amateur Naturalists, Chemists, Physicists, Astronomers, &c., &c. 8° Boston, 1892.

CONSTABLE, *Archibald.*—Travels in the Mogul Empire by Francois Bernier. A.D. 1656-1668. 8° Westminster, 1891.

DAVIES, *D. C.*—A Treatise on Earthy and other Minerals and Mining. 8° London, 1892.

FISHER, *Rev. Osmond.*—Physics of the Earth's Crust. 8° London, 1889.

FORBES, *David.*—Report on the progress of the Iron and Steel Industries in Foreign Countries. 8° P. Newcastle-upon-Tyne, 1876.

GEIKIE, *A.*—Elementary Lessons in Physical Geography. 8° London, 1892.

Titles of Books. *Donors.*

GOUIN, *Francois.*—The Art of Teaching and Studying Languages. 8° London, 1892.

HARRISON, *W. Jerome.*—Elementary Text-Book of Geology. 8° London, 1889.

HARRISON, *W. Jerome*, and WAKEFIELD, *R.*—Earth Knowledge. Parts I and II. London, 1891.

HOLLAND, *T. H.*—Preliminary Report on the Iron-Ores and Iron Industries of the Salem District. 8° P. Calcutta, 1892. THE AUTHOR.

KING, *C. W.*—The Natural History of Gems or Decorative Stones. 8° London, 1867.

KOLBE, *Dr. H.*—A short text-book of Inorganic Chemistry. 8° London, 1892.

LEPSIUS, *Richard.*—Geologie von Deutschland und den angrenzenden Gebieten. Band I, lief 3. 8° Stuttgart, 1892.

LITTLEHALES, *G. W.*—The average form of Isolated Submarine peaks, and the interval which should obtain between soundings taken to disclose the character of the bottom of the Ocean. 8° P. Washington, 1890.
REVENUE AND AGRICULTURAL DEPARTMENT.

MARCOU, *Jules.*—The Geological map of the United States and the United States Geological Survey. 8° P. Cambridge, Mass, 1892.
THE AUTHOR.

MERRILL, *George, P.*—Stones for Building and Decoration. 8° New York, 1891.

MILLS, *F. W.*—Photography applied to the microscope. 8° London, 1891.

MILNE, *John*, and BURTON, *W. K.*—The Great Earthquake of Japan, 1891. 2nd Edition. Fol. Yokohama, 1892.

NEWBERRY, *John S.*—Fossil Fishes and Fossil Plants of New Jersey and Connecticut Valley. 8° Washington, 1888.
REVENUE AND AGRICULTURAL DEPARTMENT.

" The Paleozoic Fishes of North America. 4° Washington, 1889.
REVENUE AND AGRICULTURAL DEPARTMENT.

Norwegian North Atlantic Expedition, 1876—1878. Zoology, Crinoida and Echinida, by D. C. Danielssen. 4° Christiania, 1892. THE COMMITTEE.

Paléontologie Française Terrains Tertiaires Éocéne Echinides. Tome II, liv. 26. 8° Paris, 1892.

PAMELY, *Caleb*—The Colliery Manager's Hand-book. 8° London, 1891.

PHILIPS' Handy Volume Atlas of London. 8° London, 1891.

ROSCOE, *Sir H. E.*, and SCHORLEMMER, *C.*—A treatise on Chemistry. Vol. III, part 6. 8° London, 1892.

SADTLER, *Samuel P.*—A Hand-book of Industrial Organic Chemistry. 8° Philadelphia, 1892.

SIEMENS, *C. W.*—On Puddling Iron. 8° P. London, 1868.

" On smelting Iron and Steel. 8° P. London, 1873.

STREETER, *Edwin W.*—The Great Diamonds of the World. 8° London, 1882.

THOMSON, *Sir C. Wyville*, and MURRAY, *John.*—Report on the Scientific Results of the voyage of H. M. S. "*Challenger*" during 1873—1876. Deep Sea Deposits. 4° London, 1891. INDIA OFFICE, LONDON.

TRYON, *G. W.*—Manual of Conchology. Vol. XII, part 52, and 2nd series, Vol. VI, part 28. 8° Philadelphia, 1892.

Titles of Books. *Donors.*

WALCOTT, *Charles D.*—Preliminary Notes on the discovery of a Vertebrate Fauna in Silurian (ordovician) Strata. 8° P. Rochester, 1892.
THE AUTHOR.

" The Fauna of the Lower Cambrian or Olenellus zone. 8° Washington, 1890.
REVENUE AND AGRICULTURAL DEPARTMENT.

WALLACE, *Alfred Russel.*—Island Life or the Phenomena and causes of insular Faunas and Floras including a revision and attempted solution of the problem of geological climates. 8° London, 1892.

WATTS' Dictionary of Chemistry. Vol. III, revised and entirely rewritten by H. F. Morley and M. M. Pattison-Muir. 8° London, 1892.

WEED, *W. H.*—The formation of the Travertine and Siliceous Sinter by the vegetation of hot springs. 8° P. Washington, 1890. THE AUTHOR.

WHYMPER, *Edward.*—How to use the Aneroid Barometer. 8° London, 1891.

" Travels amongst the Great Andes of the Equator. 8° London, 1891.

" Supplementary appendix to travels amongst the Great Andes of the Equator. 8° London, 1891.

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American Geologist. Vol. IX, Nos. 1—6, and X, No. 1. 8° Minneapolis, 1892.

American Journal of Science. 3rd series, Vol. XLIII, No. 258 to Vol. XLIV, No. 260. 8° New Haven, 1892.

American Naturalist. Vol. XXVI, Nos. 306-308. 8° Philadelphia, 1892.

Annalen der Physik und Chemie. Neue Folge, Band XLVI, heft 2-4. 8° Leipzig, 1892.

Annals and Magazine of Natural History. Vol. X, Nos. 55-57. 8° London, 1892.

Athenæum. Nos. 3373-3384. 4° London, 1892.

Beiblätter zu den Annalen der Physik und Chemie. Band XVI, Nos. 5-7. 8° Leipzig, 1892.

Chemical News. Vol LXV, No 1699 to Vol. LXVI, No. 1710. 4° London, 1892.

Colliery Guardian. Vol. LXIII, No. 1642 to Vol. LXIV, No. 1653. Fol. London, 1892.

Geological Magazine. New Series, Decade III, Vol. IX, Nos. 7-9. 8° London, 1892.

Indian Engieering. Vol. XII, Nos. 1-12; and supplement Vol. XI. Flsc. Calcutta, 1892. PAT. DOYLE.

Iron. Vol. XXXIX, No. 1014 to Vol XL, No. 1025. Fol. London, 1892.

Mining Journal. Vol. LXII, Nos. 2964-2975. Fol. London, 1892.

Natural Science. Vol. I, Nos. 1-6. 8° London and New York, 1892.

Nature. Vol. XLVI, Nos 1181-1192. 4° London, 1892.

Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Band I, heft 3. 8° Stuttgart, 1892.

Oil and Colourman's Journal Vol. XIII, Nos. 143-145. 4° London, 1892.

Petermann's Geographischer Mittheilungen. Band XXXVIII, Nos. 6-8. 4° Gotha, 1892. THE EDITOR.

Scientific American. Vol. LXVI, Nos. 23-26, and LXVII, Nos. 1-8. Fol. New York, 1892.

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Scientific American. Supplement. Vol. XXXIII, No. 857 to Vol. XXXIV, No. 868. Fol. New York, 1892.

The Indian Engineer. Vol. XIII, Nos. 273-284. Flsc, Calcutta, 1892.

J. MacINTYRE.

GOVERNMENT SELECTIONS, REPORTS, ETC.

BOMBAY.—Magnetical and Meteorological Observations made at the Government Observatory, Bombay, in 1890, with an appendix. Flsc, Bombay, 1892.
BOMBAY GOVERNMENT.

„ Selections from the Records of the Bombay Government. New Series. Nos. 256 and 258. Flsc., Bombay, 1892. BOMBAY GOVERNMENT.

INDIA.—Administration Report of the Marine Survey of India for 1891-92. Flsc., Bombay, 1892. BOMBAY GOVERNMENT.

„ Administration Report on Railways in India for 1891-92. Part I Flsc., Simla, 1892. GOVERNMENT OF INDIA.

„ General Report on the operations of the Survey of India Department for 1890-91. Flsc., Calcutta, 1892. SURVEY OF INDIA.

„ Quarterly Indian Army List. New Series, No. 12. 8° Calcutta, 1892.
GOVERNMENT OF INDIA.

„ Indian Meteorological Memoirs Vol. I, Part I. 4° Calcutta, 1892.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Meteorological Observations recorded at seven Stations in India in 1891, corrected and reduced. 4° Calcutta, 1892.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Monthly Weather Review for November 1891 to April 1892. 4° Calcutta, 1892. METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Register of Original Observations in 1891 and 1892, reduced and corrected, November 1891 to April 1892. 4° Calcutta, 1892.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Register of Original Observations in Madras, reduced and corrected, January 1891 to April 1892. 4° Calcutta, 1892.
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„ Report on the Meteorology of India in 1890. 4° Calcutta, 1892
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„ Selections from the Records of the Government of India in the Foreign Department. Nos. 288 and 291. Flsc., Calcutta, 1892
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MADRAS.—Madras Meridian Circle Observations for the years 1874 to 1876. 4° Madras, 1892. MADRAS GOVERNMENT.

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ADELAIDE.—Transactions of the Royal Society of South Australia. Vol XV, part I. 8° Adelaide, 1892. THE SOCIETY.

ALBANY.—Bulletin of the New York State Museum. Vol. I, No. 1. 8° Albany, 1892.
THE MUSEUM.

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ALBANY.—Forty-fourth Annual Report of the Regents of the New York State Museum for the year 1890. 8° Albany, 1892. THE MUSEUM.

BALTIMORE.—American Chemical Journal. Vol. XIII, No. 7, and XIV, No. 1. 8° Baltimore, 1891-1892. JOHNS HOPKINS UNIVERSITY.

" American Journal of Mathematics. Vol. XIV, No. 1. 4° Baltimore, 1891. JOHNS HOPKINS UNIVERSITY.

" American Journal of Philology. Vol. XII, Nos. 2-3. 8° Baltimore, 1891. JOHNS HOPKINS UNIVERSITY.

" Johns Hopkins University Circulars. Vol. XI, Nos. 98-100. 4° Baltimore, 1892. JOHNS HOPKINS UNIVERSITY.

" Johns Hopkins University Studies in Historical and Political Science. 9th series, Nos. IX-X, and 10th series, Nos. I-III. 8° Baltimore, 1891-1892. JOHNS HOPKINS UNIVERSITY.

BATAVIA.—Notulen van het Bataviaasch Genootschap van Kunsten en Wetenschappen. Deel XXX, Afl. 1. 8° Batavia, 1892. BATAVIAN SOCIETY.

" Tijdschrift voor Indische Taal-Land-en Volkenkunde. Deel XXXVI, Afl. 1. 8° Batavia, 1892. BATAVIAN SOCIETY.

" Verhandlungen van het Bataviaasch Genootschap van kunsten en Wetenschappen. Deel XLVII, Stuck 1. 8° Batavia, 1892. BATAVIAN SOCIETY.

BERLIN.—Abhandlungen der Koniglich Preussischen Geologischen Landesanstalt. Neue Folge, heft. 5. 8° Berlin, 1892. THE INSTITUTE.

" Abhandlungen zur geologischen Specialkarte von Preussen und den Thüringischen Staaten. Band IX, heft. 3 with Atlas, and Band X, heft. 3. 8° and 4° Berlin, 1891. THE INSTITUTE.

" Zeitschrift der Deutschen Geologischen Gesellschaft. Band XLIII, heft. 4, and XLIV, heft. 1. 8° Berlin, 1892. THE SOCIETY.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1893. [May

Notes *on the* earthquake *in* Balúchistán *on the* 20th December 1892, *by* C. L. GRIESBACH, C.I.E., *Superintendent, Geological Survey of India.*

Early on the morning of the 20th December 1892 an earthquake was felt over the greater portion of Balúchistán, concerning which a few facts have been collected by several officials of the North-Western Railway and also by myself, which I have condensed in the following notes.

Through the courtesy of Mr. C. W. Hodson, the Engineer-in-Chief of the Frontier Section of the North-Western Railway, I am enabled to give some particulars which have been reported by officials serving under his orders, and after Christmas I visited the Kójak range in company of that gentleman to inspect the damage caused by the earthquake. Mr. L. Gordon, District Traffic Superintendent, has taken very instructive photographs of the effects of this earthquake, which were obligingly placed at my disposal ; reproductions of two of them being given here.

I quote herewith extracts from the report of the Executive Engineer at Shalabagh :

"On the 20th December, at 5-40 A.M. (Madras time[1]), this district was visited by a somewhat severe earthquake. It was followed by several lesser shocks, and at Shalabagh[2] they continued at frequent intervals during the day, and have occurred at frequent intervals up to the present date[3]. The exact time of the shock was shewn by the stoppage of a pendulum clock in my office.

* * * *

"*Effects at Sanzal*[4].—The station building at this place has apparently suffered most. Its close proximity to the line of fissure which runs in a north-east and south-west line about half a mile below the station, being probably the cause. The water tower is standing, but most of the turrets are loose * *. The oscillation of the ground caused the water to spill out of the iron tanks * *. The station building including the station master's and signaller's quarters and out-houses are very badly shaken, and will require rebuilding to a considerable extent. The whole of the chimneys have been thrown down.

[1] At Quetta the shock was felt at 5-46 A.M.; the distance from Shalabagh to Quetta being 53 miles in a straight line.

[2] Shalabagh is a station on the Sind-Peshin Railway at the eastern entrance to the Kójak tunnel.

[3] 22nd December.

[4] Sanzal is the first station on the western side of the Kójak tunnel.

"Lower down the line, at mile 643, * * the only serious damage to the permanent way occurred. There is visible at this spot to the eye, for a considerable distance, as far indeed as the eye can reach, a line of division in the soil, and where this intersects the railway at an angle of about 15° or 20°, the metals of the permanent-way were distorted in a most extraordinary way, the pairs of rails in each line immediately above the crack in the ground having suffered most. They were bent into a sinuous curve which is represented approximately in the annexed tracing and the photograph.

* * * *

"I have followed the line of fissure in the surface of the ground for a considerable distance on each side of the line, and it extends beyond Old Chaman on the one side for several miles I am told; I myself followed it for one mile beyond Old Chaman and could then see it extending far into the distance. In the other direction I am informed by an Achakzai, who had just come from there, it cuts the line of the Khwája Amran range obliquely, and can be traced to the peak of that name, some 18 miles off.

"There appears to have been a shearing action on the surface of the ground, the line of shear being tangential to the line of cleavage.

"The rails having resisted this motion were crumpled up in consequence. The joints in the rails on each side of the contortion have all been closed up, although, of course, originally, clearance for expansion had been left.

"The down line has now been put in order; the rails which were removed consisted of·

4 pairs of 30′	=	120′
1 pair ,, 24′	=	24′
Total	=	144′

and these have been replaced by—

5 pairs of 24′	=	120′
1 pair ,, 21′6″	=	21′ 6″
Total	=	141′ 6″

thus showing that the line has been contracted approximately 2½ feet.

"While tracing the crack in the ground through Old Chaman, I found that it crossed all the collecting pipes of the Military Works Department at Old Chaman. Most of these pipes crossed the crack at approximately a right angle and had not suffered, but one 1½ inch pipe which cut it obliquely was pushed up and off the ground! and formed a sort of arch over the crack."

In addition to the above, the report of that officer contains a detailed statement of damages to railway buildings at Shalabagh which were very severe, of a slight damage to the defences on the western side of the Kójak tunnel and of the effects on banks and bridges on the line, which, though showing the force of the shocks, can tell us little beyond that there was a severe earthquake, which had found out the weakest parts of those buildings and works.

A week after the earthquake I visited the Kójak range in company of Mr. Hodson. We first inspected the damage done by the earthquake to the houses and works in the neighbourhood of Shalabagh station at the eastern entrance of the Kójak tunnel; though there was much mischief done to buildings, etc., not much could be learned from these effects of the earthquake. If the scene of destruction had been in a closely built town, it might have been possible to detect some method, if I might use the expression, in the damage done, but at Shalabagh the houses are far apart, built on unequal hilly ground, and the workmanship in the buildings, mostly constructed of sun-dried bricks, is also very unequal, so that all one can say is that the shocks of earthquake have affected all the weak points of these buildings, many of which will have to be entirely reconstructed.

The Kójak tunnel fortunately escaped serious damage, though it is interesting to hear that the water-supply from some springs which issue inside the tunnel and which now escapes in a regular drain from the western (or Chaman side) of the tunnel, was considerably increased after the earthquake shocks.

The block-house which defends that entrance to the tunnel received some slight damage in the shape of cracks which have appeared in the solid masonry.

The effects of the earthquake shocks are visible almost all along the made banks on which the permanent-way is laid between the tunnel and Sanzal station. In their case the earthquake acted most beneficially, inasmuch as the artificially built-up material of these banks was well shaken down, and, though the latter have sunk here and there and cracks have appeared in places, their settling down and consolidating was equal to a season's rain, as the engineer of that section reports.

The real interest of the earthquake, however, centred in the damage done between Sanzal station and Old Chaman. A glance at the map of the Kójak pass (No. 87 $\frac{\text{N. W.}}{4}$ & $\frac{\text{N. W.}}{3 \,\&\, 4}$, scale 1 mile — 2 inches) will explain the scene of the earthquake.

The line of railway descends to New Chaman from the Kójak tunnel in several great curves and in zig-zag fashion. Sanzal station is situated near the upper margin of a great and rapidly descending glacis, which slopes down from the Kójak range to the great plain in which New Chaman is situated.

About half a mile west of Sanzal station will be observed a path which runs from the Khwája Amran peak (8,864′) in a north-north-east direction along this glacis. It appears that at the immediate foot of the Kójak range a great number of springs rise, close to which of course there is always a certain amount of grazing to be found, and thus this line of springs has been connected by a regular path, made by flocks passing along these patches of pasture-land. The water escaping from these springs has furrowed and denuded the glacis into an infinite number of small channels which are well shown in the map. There is another feature which is at once apparent, and that is that the path with its springs and patches of grazing grounds all lie as it were in a natural depression, running parallel with the range of the Kójak itself, whilst immediately to the westwards of it the ground of the glacis rises somewhat, before finally descending to the plains. This is well marked near Old Chaman, the foot of which is built on this rising ground.

About 7 to 8 miles south of Old Chaman this insignificant rise of ground becomes an auxiliary range of hills, which runs west and parallel with the Kójak range towards the Khwája Amran peak itself.

I expect to have further opportunities of geologically examining this ground when the weather will permit in the spring; until then I will only state my belief that the present path which connects the springs described indicates, as near as can be, the existence of an old fault line. At the present time I have no further proof for it than this, that as far as I have been able to ascertain during this hurried visit, the line of path is, roughly speaking, also a geological boundary between the slaty formation of the Kójak and a grey earthy limestone, the latter of which is very probably of upper cretaceous or lower eocene age; this boundary being here suspiciously abnormal in appearance. The springs which rise along it tend further to the opinion that they appear along a line of dislocation, which view is further

strengthened by the fact that in the neighbourhood of the springs not only a kind of travertine is visible, but a curious breccia, consisting of debris of both the limestone and the slates of the Kójak and cemented by calcareous rock, is *in situ* and in strong force all along the line of path, but not off it, which breccia I now look upon as a fault-rock. The glacis itself is chiefly made up of recent deposits, fans from the range above, but I hope to discover a more exposed section further south, where the structure of this dislocation, if it is one, will be clearly demonstrated. Finally, but not least, the fault seems to be proved by the earthquake itself, which has originated in a further, though slight dislocation along a line, which exactly and absolutely coincides with the present path connecting the numerous springs.

In my theory explanatory of this earthquake, I therefore start with the assumption that an old line of fault exists, which runs more or less parallel with the Kójak range itself. In a mountain range entirely formed by flexures, which chiefly correspond to the strike of the range itself, such faults usually exist on a large scale. The lateral pressure which caused the folding of the strata in such cases frequently results in one or several systems of dislocations, as we may observe in numerous instances within folded mountain ranges.

What I could see of the effects of the earthquake in that region is soon told, and has been already described in the report of the Executive Engineer of Shalabagh. I will omit the damage done to station or other buildings and describe at once the fissure which has been mentioned above. It crosses the line of railway below Sanzal station at mile 643 and absolutely coincides with the line of path aforementioned, never being further away from it than a few yards. It is therefore practically laid down on the large scale map with sufficient accuracy. I followed it north and south of where it traverses the line for several miles, and could moreover see it clearly in the distance following the same direction for very many miles. Mr. Hodson, to whom I am indebted for additional evidence, has had the fissure traced by some of his subordinates as far as the Khwája Amran peak, where it is said to bifurcate, one of the cracks going east of the peak, the other west of it. The country is now under snow, and we shall have to wait till the spring weather permits further explorations.

But a few facts can be learned from the fissure as we see it. All the features connected with it tend to the fact that the entire area west of the fissure has not only slightly subsided, but also bodily moved southwards. The lowering of the area seems to be about 8 inches to a foot, but exact measurements are difficult, and the subsidence is probably not equal at all points of the line of fissure. But it is fairly exactly proved that this area has shifted at least 2 feet to 2½ feet southwards. The fissure itself is mostly closed, the ground on the surface being generally soft debris, but here and there a gaping fissure has resulted, from a few inches in width to several feet, the sides of which seem to be vertical. Fragments of turf and dry masses of the ground adjoining the crack have been carried along by the movement southwards, if the mass came from the eastern side of the fissure, or the reverse if it was detached from the western margin of the dislocation. But where the movement may best be observed is in the permanent-way itself and in pipes crossing the fissure. The mass of the western area having pressed southwards and against the line of fissure, the rails which cross the latter have been forced into curves as already

well described in the report quoted, and the joints left open for expansion, have all been closed, as the movement was exerted in a direction more or less parallel with the permanent-way.

Very nicely illustrated was the movement by the damage done to the water-pipes. One, which crosses the fissure obliquely, was bent, having no other means of yielding to the pressure. The others have merely been shifted and lifted out of the surrounding loose earth and debris. Different measurements may be obtained along the various points of the line of fissure. Here and there the dislocation of the pipes does not appear to be more than from a foot to eighteen inches or even less than that. It is probable that also within the mass of the ground adjoining the fissure compression had been active, and here and there where the strata were of a yielding nature has resulted in very little dislocation apparently of the ground itself, whereas along other points the effect is much greater. So far the largest measurement taken amounts to a shift of 2 feet 6 inches; this was the result in the permanent-way at mile 643 and near several irrigation drains, which crossed the fissure at rightangles, and which have suffered a displacement of that larger amount. It is highly probable, considering the variation of the measurements consequent on the difference in lithological character of the ground through which the fissure runs, that the sum total of the movement exceeded 2½ feet considerably, but of that we have so far no direct proof.

From the foregoing it would appear that the process of contracting and folding, with resultant dislocations, of this area in Balúchistán, is still proceeding. At some previous date in the history of the Khwája Amran Mountain range this process of compression, as it must have been, has led to the formation of the line of fault, conjectured in these notes; the process, from whatever cause, is still active, and the tension having become too great has further resulted in a slight increase to the amount of dislocation already in existence. The two areas adjoining the fissure have moved about 8 inches vertically, and a couple or more feet horizontally from each other, which sudden establishment of a temporary equilibrium in this tension is no doubt quite sufficient to account for the vibration of the ground to a considerable distance, which vibration is commonly called an earthquake.

I need scarcely say that there is no indication of any kind which would point to the existence of volcanic activity at, or anywhere near, the area affected by this earthquake; I mention this only, because it was also in this case, as in other instances elsewhere, the popular theory advanced by many of those who personally experienced the alarming symptoms of this perfectly natural phenomenon.

Further Note *on* Burmite, *a new amber-like fossil resin from* Upper Burma. *By* DR. OTTO HELM of Danzig. (Translated from the German by PROFESSOR BRUHL, Civil Engineering College, Sibpur.)

Having received from the Director of the Geological Survey of India additional and sufficient quantities of the amber-like fossil resin occurring in Burma,[1]

[1] See *Records Geol. Surv.* XXV, 180.

I have continued its chemical and physical examination. My researches, the results of which I give in what follows, have rendered it evident, that we have to deal with a remarkable fossil resin, which differs essentially from all fossil resins known hitherto, and to which I have given the name of Burmite. The specimens before me were found at the Nangotaema Hill, near Maingkhwan, and consist of eleven larger pieces and various fragments; two of the pieces having been artificially worked. The majority of the pieces have a colour which varies from light brownish-red to dark-brown, and they are semi-transparent; other pieces are ruby-red and transparent; two are golden-yellow and two wine-yellow. The weathered crust which covers the pieces is variously coloured, and differs also in other respects, according as the pieces, when *in situ*, were exposed to the action of the atmosphere or underwent a process of fossilisation in the absence of air. Those pieces which show least signs of weathering, are surrounded by a thin yellowish-brown or brownish-black crust; the more weathered pieces are covered with a yellowish-brown or dark-brown layer of a thickness of 1-2 mm., beneath which there are often some ruby-red layers. These layers are easily detached. Some pieces are traversed by cracks filled with crystallized calcium carbonate.

The pieces which have not undergone the process of weathering are, generally speaking, harder than succinite; their hardness lies between 2·5 and 3. They also exhibit a greater power of resistance to the action of tools than is shown by succinite. On fracture it breaks into fragments with shining, flat-conchoidal surfaces, which have a resinous feel. All pieces fluoresce more or less, emitting a bluish light, which is especially well seen on polished surfaces of pieces of the dark-red or brownish-red variety.

The majority of the pieces of burmite, and especially those which are semi-transparent and of a dark colour, exhibit under the microscope small roundish and longish, often elongated bodies, which are coloured more or less brown. These bodies owe evidently their origin to sap which exuded together with the resin from the mother-plant and, like the resin, became hardened during the process of fossilisation. On viewing these structures, it frequently becomes clear that we have to deal with cavities the walls of which are lined with dried-up amorphous organic substance. The less a specimen of burmite contains of these by-products, the purer and prettier is its colour.

During combustion, burmite emits a peculiar aromatic colour which attacks the mucous membrane of the nose and throat only slightly. The fusing-point could not be ascertained, because burmite begins to decompose before it fuses.

Already in my first report I have described the behaviour of burmite towards polarised light, and when subjected to dry distillation. The result of repeated experiments was the same. Again I ascertained the presence of formic acid in the distillate, as well as the absence of succinic acid. On the other hand, the aqueous portion of the distillate contained a small quantity of a substance which, from its chemical behaviour, I believe to be pyrogallol. The brownish-yellow empyreumatic oil, which distils over together with the aqueous portion, contains sulphur derived from the sulphur which forms a part of the organic substance of the resin. The resin itself contains 0·013 to 0·021 per cent. of this chemically combined organic sulphur.

The ultimate composition of burmite, as evidenced by an analysis of the substance, is—

Carbon	80·05
Hydrogen	11·50
Oxygen	8·43
Sulphur	0·02
TOTAL	100·00

I determined the specific gravity from recently received pieces; it lies between 1·030 and 1·095.

I have once more studied the behaviour of burmite towards solvents, using average samples. Alcohol dissolves 5-6·8 per cent. The solution is rendered turbid on addition of an alcoholic solution of lead acetate; on warming, the liquid becomes gradually clear. Silver nitrate gives a white precipitate; ferric chloride colours the solution yellow. Ether dissolves 2·4 to 4·2 per cent. of burmite; the solution leaves a light-yellow resin on evaporation. Chloroform dissolves 11·8 per cent. of the resin, petroleum naphtha 2·2 per cent., carbon disulphide 4·6 per cent., oil of turpentine 18·5 per cent. The quantity of ash left by burmite on combustion, varies according to the purity of the substance; the pure clear pieces leave 0·2 per cent., the turbid, red pieces 0·6 per cent. The ash consists of carbonate and sulphate of lime and oxide of iron. Those pieces which are very turbid and full of impurities leave 4·6 per cent. of ash on combustion, which consists chiefly of ferric oxide.

I have already, in my first report, described the behaviour of burmite towards strong mineral acids. On rubbing, it becomes strongly excited with negative electricity.

According to what has been stated in the preceding account about the chemical and physical properties of this resin, it is distinguished from succinite, the fossil resin of the Baltic, by the absence of succinic acid. From the other known amber-like resins of the group of the retinites, burmite is distinguished by its hardness and toughness, which render it fit for carving and turning; further, by its chemical composition, its vivid colours, and its fluorescence. The latter property, burmite shares with the Sicilian Simetite[1]; but the latter is coloured still more vividly, especially in red tints; further Simetite is richer in organically combined sulphur and less resistant to solvents than burmite. From ambrite, which occurs in Auckland[2], burmite is chiefly distinguished by its low percentage of oxygen and by its being but little soluble in carbon bisulphide.

Wood or other vegetable remains may possibly be found in burmite, from which conclusions could be drawn as to the plants from which the resin exuded; for the present we can only state that especially the typical brownish-red pieces of burmite include cloudy accumulations and grains, lying in cavities, of a substance which I consider as derived from the juices which, together with the resin, exuded from the mother-plant and which, with the resin, was subjected to the process of fossilisation.

[1] Vide *Malphigia, anno I, fasc. II, 1886.*
[2] Vide *Verhandl. der. K. K. geolog. Reichsanst*, *Vienna*, 1861, p. 5.

Besides the fossil resin, of which the preceding is an account, I received from the Director of the Geological Survey of India two other samples, also found in Burma:—(1) one from Wuntho in the Shwebo district. This consists of pieces which are very brittle and have a golden-yellow or yellowish-brown colour. The resin is included in and respectively combined with, carbonaceous slate; (2) one from Yenangyat in the Pakoko district; it consists of small fragments which are semi-transparent and of a reddish-yellow colour. Neither of these resins contains succinic acid; whether they are identical with burmite, I was unable to ascertain, as the quantity at my disposal was not sufficient for complete examination.

The Survey is greatly indebted to Dr. Helm for this and his previous contribution; and for his thorough examination of the specimens of this new fossil resin which he has enabled us to add to the list of Indian mineral species. I am glad to see the ruby tint which I have already noticed as likely to give some specimens, when judiciously cut, of burmite a better character than is anticipated by Dr. Noetling, is also, distinguished as characteristic. I hope yet to give this charm of the stone some display in the Survey Museum.—*Ed.*

Note *on the* Alluvial deposits *and* Subterranean water-supply *of* Rangoon, *by* R. D. OLDHAM, A.R.S.M., *Superintendent, Geological Survey of India.* (With a map.)

Attention has recently been drawn, in connection with the increase of the water-supply of Rangoon, to a number of tube wells, sunk during the last few years in the premises of several of the mills of that city, some of which have yielded a useful supply of fresh water, while in others only brackish was met with. In many cases no record of what was passed through has been preserved, and in some it has subsequently been lost, but a sufficient number of sections have been preserved to make it worth while putting them on record.

The borings are situated on or near the banks of the Rangoon river and the Poozoondoung creek, and lie in a roughly semicircular zone round the termination of the Pegu Yoma in the Shway Dagon pagada hill. The sections preserved all present the same type of structure; the surface beds consist of the "newer alluvium" of Theobald, characterised by its finer grain and generally bluish colour, while the lower part of the bore hole lies in the coarser grained "older alluvium," marked by its generally sandy or gravelly texture and buff or reddish colour. They are driven down to beds of gravel in which water of some kind, whether fresh or brackish, was obtained, but in interpreting the section it is necessary to bear in mind the process by which the wells were sunk. They are cased with iron piping of from $2\frac{1}{2}''$ to $4''$ internal diameter, which was sunk by the simple process of forcing a stream of water down a smaller tube of from $1''$ to $2''$ bore, inserted in the centre of the outer casing. The stream of water ascending the annular space between the two tubes carried with it the material washed from the bottom of the bore, and so enabled the two tubes to be sunk simultaneously; when the well was completed, the inner tube was withdrawn and a pump attached to the outer one. This process appears to be simple, inexpensive, expeditious, and effectual, though of course only applicable in soft and not too coarse grained

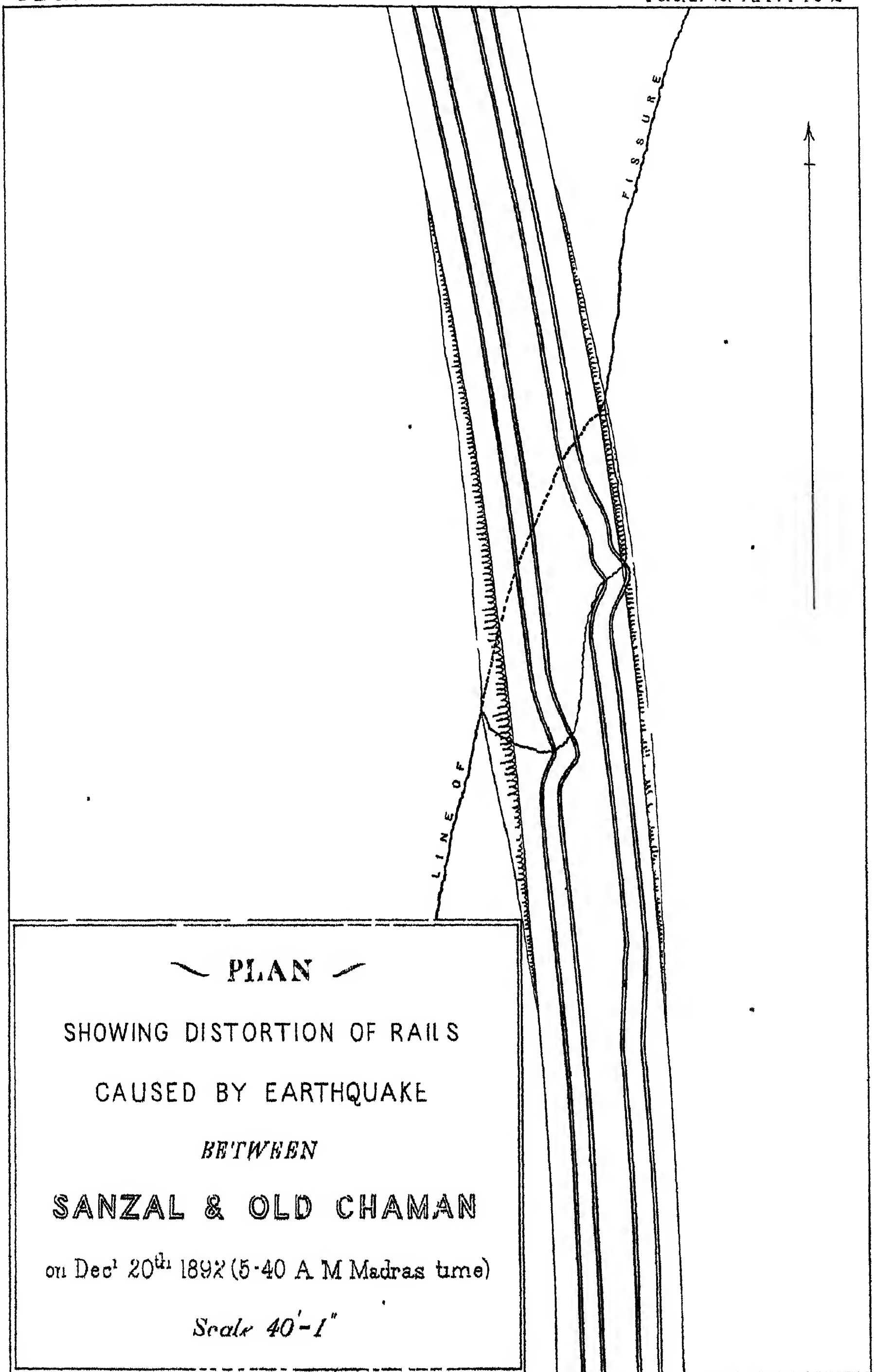
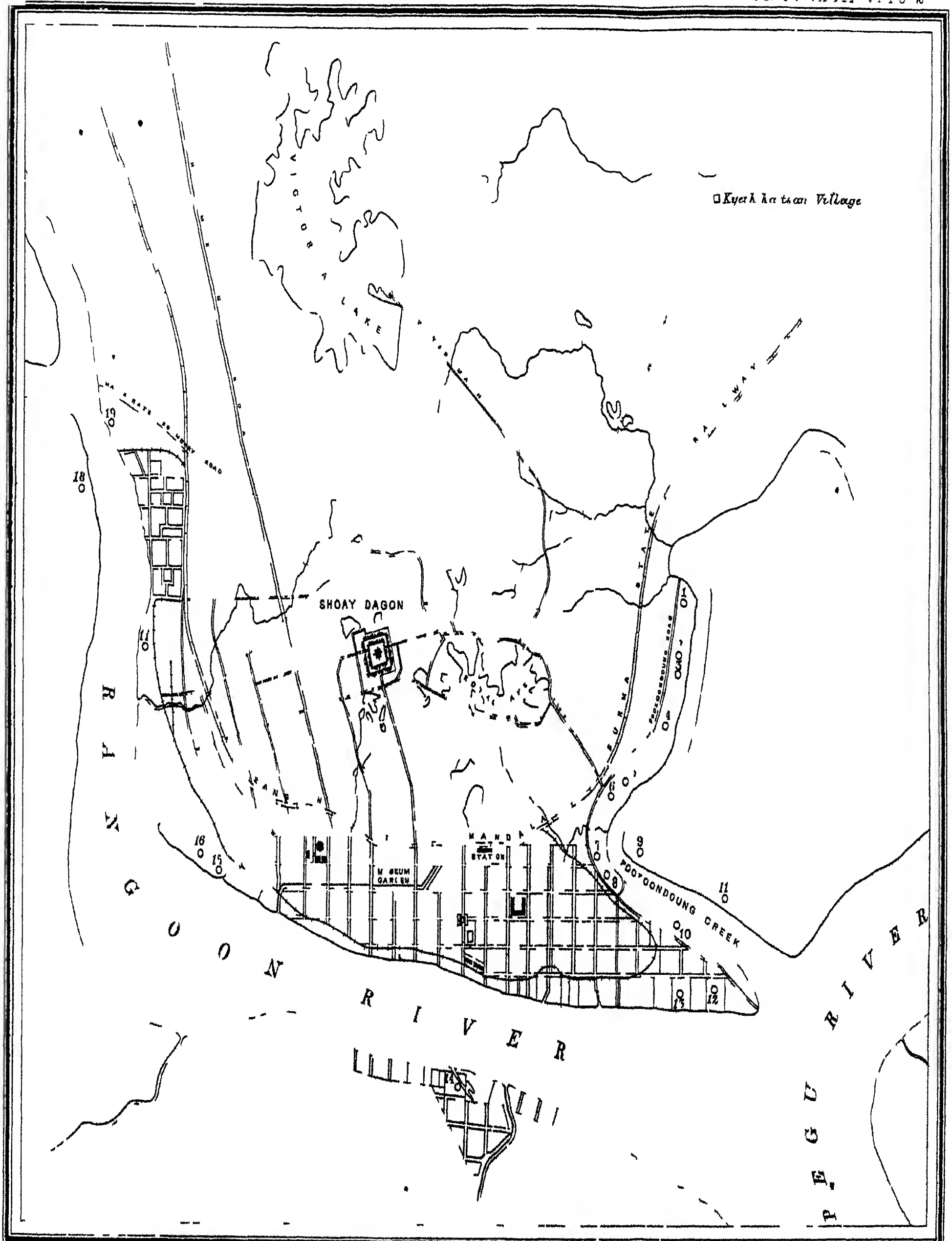

FISSURE
LINE OF
PLAN
SHOWING DISTORTION OF RAILS
CAUSED BY EARTHQUAKE
BETWEEN
SANZAL & OLD CHAMAN
on Decr 20th 1892 (5·40 A M Madras time)
Scale 40'–1"

Photo-etching.

Survey of India Offices, Calcutta, April 1893

View showing distortion of Rails caused by Earthquake between Sanzal & Old Chaman

Photo etching



Lithographed & Printed at Geological Survey Office

PLAN OF RANGOON

Showing position of deep borings

Scale 1" = 1 Mile

deposits, but it has an effect on the stuff washed out that must be allowed for. The stream of water which is sufficient to wash away fine clays or sands, would be insufficient to bring up coarse grit and small pebbles to the surface. Consequently if pebbles are mixed with fine sand or clayey matter, the stream, which has sufficient power to bring the pebbles to the surface, will wash away all the finer matter, and so what would seem to be a clean gravel, to judge from the washed material brought up, might really be a mixture of pebbles and clayey sand, of very little value as a source of water.

A report on the bearing of my observations on the proposal to obtain an increased supply of water for the town of Rangoon by boring, has been submitted to the Rangoon Municipality, and need not be ieproduced here in full, though the main points may be summarised.

The question presents itself in two aspects, that of the quality and the quantity of the available supply. To take the latter first, all the wells on the Poozoondoung creek above Messrs. Zaretskey Bock & Co.'s mill have yielded fresh water of excellent quality, while all those lower down have only given more or less brackish water. It so happens that just where the limit between the fresh and brackish wells lies, there are some lateritic rocks exposed in the Poonzoondoung creek at low water, and these have been supposed to mark the crest of a ridge of rock, separating the fresh water, whose source is supposed to lie to the north, from the brackish water to the south. It is needless to say that this is not so. There is nothing to show that the water bearing gravels are not continuous underground, while there is every indication that they aie so, and that there is a continuous outflow of water from the outcrop of the gravels to the sea. The lateritic rocks in the Poozoondoung creek doubtless indicate an outcrop of the older alluvial gravels and as we know that they rise to the surface just across the Pegu river, they are very probably exposed in its bed. Here the salt water would obtain access to the water bearing gravels, and the internal movements set up by the variations of pressure due to the rise and fall of the tide, causes a contamination, which extends as far towards the original source of the water as the outward flowing current will allow. That this is the true explanation of the salinity of some of the wells is shown by the recurrence of fresh water wells up the Rangoon river as soon as they come within the influence of the more extensive collecting ground on the western side of the termination of the Pegu Yoma; the brackish wells being not only close to where salt water can get access to the gravels, but opposite the comparatively limited collecting ground at the termination of the Yoma. It may, therefore, be confidently predicted that wells sunk to strike the same gravels further to the north, that is further away from the outlet to the sea and more within the influence of the principal collecting ground, will be certain to find fresh water.

The quantity procurable from each well is a much more doubtful matter. The yield of the existing wells varies from 2,500 to 70,000 gallons a day, in no case was it anything like the full amount that the tube was capable of discharging; in every case but one, where the trial had not been made, I was informed that more vigorous pumping did not appreciably increase the dischage. We may consequently take it that the amount obtained from the wells is the maximum they are capable of yielding, and as the yield of different wells varies very much, one of the poorest being found within a few hundred feet of one of the richest, it seems that the

gravels are subject to local and capricious variations of permeability which makes it impossible to anticipate a large average yield in so many wells as would have to be sunk to obtain the amount required for the supply of Rangoon.

The wells that have been sunk so far are not artesian, the natural water-level in them is from 5 to 11 feet below the surface of the ground. They are indeed situated so close to the outlet of the water in the gravels to the sea that it would be impossible for there to be any pressure sufficient to force the water above the surface. This has the effect of diminishing the effective pressure in the well and consequently its yield. Possibly artesian conditions might be found further inland, where there is a greater resistance to be encountered between the point where the well is sunk and the outlet to the sea, and if so a larger supply would be obtained by pumping, though the elevation of the outcrop of these gravels is so small that no very great increase of pressure, and consequently of yield can be expected from this cause. A large number of wells will, therefore, have to be sunk if the requisite supply of water is to be obtained, and it seems probable that, when the estimates are made out, it will be found that the cost will be nearly if not quite as great as for the construction of a storage reservoir, while the cost of maintenance and uncertainty of success will be much greater.

Appendix No. 1.—Detailed sections of borings.

Most of these sections have been preserved in glass fronted boxes, in which the different layers are arranged one above the other. In some cases this has been done to scale, and there was no difficulty in determining the depths and thicknesses, in others no fixed scale was followed, and the depths are indicated by paper slips affixed to the glass; a much inferior plan for when, as has sometimes happened, any of these labels have peeled off, it is impossible to determine the true thickness of some of the layers. Where I have not seen the specimens, or none have been preserved, the section is given by repute. The term grit is used to indicate a texture intermediate between that of sand and of gravel, the limits of size of the individual grains may be taken as $\frac{1}{32}$ and $\frac{1}{8}$ inch. The horizontal line indicates the base of the newer alluvium.

No. 1. Mohr Bros.

There are two wells, the section of the deepest is—

0—109 ft. fine grey clayey silt.
109—136 „ fine grey sand.
136—180 „ grey clayey silt.
180—190 „ yellowish sand (silt of the newer alluvium mixed with sand grains of the older).

190—210 ft. sand.
210—220 „ fine gravel ranging to $\frac{1}{4}''$ diameter.
220—270 „ coarser gravel, some pebbles as much as an inch in diameter.
below 270 feet, yellow sand again.

No. 2. Bulloch Bros. & Co.

One well, section said to be—

0—90 ft. clay.
90—96 „ sand.
96—220 „ clay.
220—240 „ yellow sand and gravel.

No. 3. Dickmann Barkhausen & Co.
One well, 242 feet deep. No record.

No. 4. Steel Bros. & Co. Upper mill.

Two wells, 50 feet apart. There is a distinct difference in the water of the two. One contains a small proportion of oily matter, probably petroleum, which floats on the surface of the water. Section—

0— 30	ft.	fine brown silt.
30— 40	„	dirty yellowish sand.
40— 60	„	grey sandy silt.
60— 70	„	fine sand.
70— 80	„	yellowish sand.
80— 85	ft.	fine grey sand.
85—100	„	brown earth.
100—	„	yellow sand.
—175	„	coarse grit and sand.
175—190	„	coarse grit.
190—210	„	fine gravel.
210—238	„	gravel ranging to 1/2 inch in diameter.

No 5. Steel Bros. & Co. Middle mill. Section—

0— 85	ft.	grey clayey silt.
85 — 99	„	fine sand.
99 —100	„	grey sandy silt.
100—118	„	fine grey sand.
118—122	„	grey sand with yellowish grains.
122—130	„	fine grey silt.
130—145	ft.	clean sand.
145—150	„	coarse grit with some fragments ranging to ¼ inch in diameter.
150—155	„	grey silt.
155—160	„	coarse sand mixed with small ferruginous concretions.
160—176	„	fine clean sand.
176—180	„	fine reddish sand.
180—190	„	coarse sand.
190—195	„	medium grained yellow sand.
195—198	„	grit.
198—203	„	coarse grit with some larger fragments.
203—229	„	gravel ranging to ¼ inch.

No. 6. Kruger & Co.

Section lost. At about 250 feet, a large number of shells in a very good state of preservation and in some cases quite fresh looking were brought up. The forms are all marine littoral, comprising the genera, *Cardium*, *Arca*, *Venus*, *Solen*, besides fragments of polyzoa. The species appear to be living ones.

No. 9. Zaretskey Book & Co. Section—

0— 30	ft.	grey silt.
30— 42	„	fine brownish sand.
42— 55	„	small ferruginous concretions.

55—125 ft grey clayey silt.
123—217, grey sand.

217—220 ft sub-angular gravel.
220—249 „ fine pale buff sand.
249—254 „ pale yellow sand.
254—257 „ coarse grit and sand.
257—289 „ pale yellow sand.
289— „ coarse grit and sand.

Through the courtesy of the proprietors this well was pumped for me with an open mouth. It was found that the well gave 1,200 gallons an hour with a lowering of the surface level of 8 feet.

No. 7. Steel Brothers & Co. Lower mill.

No record except that the water was brackish.

No. 8. Rowett & Co.

Two wells were sunk, both were failures. No further record.

No. 10. Bulloch Brothers & Co. Section—

0— 25 ft. fine clayey silt.
25— 52 „ fine sandy silt.
52— 70 „ fine grey sand.
70—108 „ silt.
108—118 „ fine grey sand.
118—170 „ alternations of more or less sandy and clayey silt.
170—256 „ grey sand of various shades.
256—265 „ grey sand with some yellow grains.

265—275 ft. yellow sand.
275—282 „ grit.
282—302 „ sharp yellow sand.
302—320 „ gravel ranging to ¼ inch.

No. 11. Arracan Co.
Two wells sunk to 240 and 245 feet; water bad. No further record.

No. 12. Arracan Co.
One well of 140 feet. Water not good. No further record.

No. 13. Victoria Oil works. Section—

0— 20 ft. grey clayey silt.
20— 80 „ fine grey sand.

80—100 ft yellowish sand.
100—120 „ fine sub-angular gravel.
120—134 „ pepper and salt grey sand.
134—155 „ sand with small pebbles.
155—190 „ sand.
190—215 „ small sub-angular gravel.
215—218 „ sand.
218—230 „ gravel mostly small, imperfectly rounded, with some fragments of ¾ inch across.
230—236 „ fine sand.
236—240 „ gravel as before.
240—250 „ fine, grey sandy silt.
250—257 „ coarse grit.

257—265 ft. fine white sand.
265—273 „ sand and grit.
273—276 „ white sand.
276—279 „ white grit.
279— „ gravel, ¼ to ¾ inch.

No. 14. Irrawady Flotilla Co.
One well of 170 feet, water brackish. No further records.

No. 15. McGregor Brothers & Co.
Section said to be—

0— 50 ft. blue clay.
50— 62 „ red clay.
62— 96 „ sand.
96—224 „ gravel, then sand and thin beds of white clay.
224—228 „ gravel.

No. 16. Foucar Brothers & Co.
No record.

No. 17. Bulloch Brothers & Co. Section—

0— 30 ft. brownish silt.
30— 43 „ grey silt.

43— 62 ft. brick red clayey matter (soft laterite ?)
62— 68 „ fine buff sand.
68— 75 „ fine pale greyish sand.
75—110 „ yellow sand.
110—130 „ clean sharp sand.
130—148 „ grit.
148—161 „ yellowish sharp sand.
161—165 „ fine brown sand.
165—171 „ coarse sand.
171—180 „ coarse sub-angular grit.
180—185 „ gravel up to an inch in diameter.

No. 18. Heatherington Gray & Co.
One well of 250 ft. Water bad; no record.

No. 19. Mohr Brothers & Co. Section—

0— ft. fine grey silt.
—196 „ grey silt mixed with grains of reddish sand.

196— ft. grey sand with some small pebbles.
—210 „ clean yellow sand.
210—215 „ coarse sand.
215— „ small gravel.
—224 „ coarse grit.
224—230 „ fine grit and coarse sand.
230—242 „ sub-angular gravel ranging to ¼ inch.

Appendix No. 2,—Analyses of water from the wells, by the Chemical Examiner to the Burma Government.

No. of well.	Total solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.
	Grains per gallon.		Parts per million.	
No. 1	8 3	·5	·01	·00
No. 2	12·6	4·1	·27	·02
No. 3	15·3	4 3	·11	·00
No. 4	16·8	3·9	·16	·04
No. 5	5 3	·3	·02	·01
No. 6	8 8	3·7	·24	·08
No. 9	5 7	·7	·02	·01
No. 11	232 4	108 6	·52	...
No. 12	125 3	49·0	·40	·20
No. 15	7 7	·5	·03	·02
No. 16	6 7	·3	·04	·02
No. 17	6 33	·7	·03	·02

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 15.—ENDING 30TH APRIL 1893.

Director's Office, Calcutta, 30th April 1893.

A slight change in the posting of the officers during the present season has been made owing to the desire of the Baluchistan Agency for a more detailed survey of the coal outcrops in what has come to be called the Quetta coalfield, which lies in the Spin Karez, Lés, and Ás Tangi valleys of the hill range to the east and south-east of that town. Mr. Dallas Edwards, on completion of his construction of a map of the Bhaganwala coal-field in the Salt Range under Mr. T. D. LaTouche, was transferred to Mr. Griesbach's survey party in Baluchistan.

Mr. R. D. Oldham was deputed for a short time to Upper Burma at the end of March. In the course of a short visit to the Yenang-young oilfield it was found that the outcrop of the ferruginous band mentioned in Dr. Nóetling's report runs in a closed oval round the oilfield, and that the productive area is confined to the highest portion of a rise in the crest of the anticlinal. The oil appears to have been concentrated in a small area whose limits have already been very nearly defined, and there is no reason to expect any important extension of the area of this

oilfield, though others will very probably be discovered in course of time. The marked diminution in the yield of the deeper native wells between the dates of Dr. Nöetling's two reports, which was supposed to indicate an exhaustion of the field, was found to be partly due to a gradual silting up of the wells and consequent apparent diminution of their depth. This filling up has the natural effect of diminishing the yield of oil, and there did not seem to be any means of determining how far the apparent exhaustion of the deeper wells was due to this cause, and how far it was due to a progressive exhaustion of the oilfield. Even if the oilbearing sandstones tapped by the native wells are being exhausted, there seems still a large supply to be procurable by deeper borings, which tap a different series of oil sands.

An investigation was also made into the proposal made by Dr. Pedley to obtain the required increase of water-supply for Rangoon by borings instead of a storage reservoir. A special report was submitted to the Burma Government, and a short paper dealing with the principal points is published in this number of the Records.

The Director was on tour in the Punjab from the 18th March to the 10th of April in connection with the proposed speculative boring for oil at Sukkur on the Indus, and at the Bhaganwala coalfield in the Salt Range. The Sukkur boring still waits arrangement for utilization of the oil-well machinery and plant used at the now discontinued oil operations in Baluchistan, and the securing the services of a Canadian well driller.

The closer examination of the Bhaganwala coalfield by boring under the conduct of Mr. LaTouche is still proceeding, but a visit to the old workings of the eastern end of the field, which have been considerably extended by drifting made under direction of Mr. H. Luckstedt, Executive Engineer of the North-Western Railway Administration, show that a much larger area of the coal seams, with an average thickness of 3½ feet, can be worked out than was anticipated. The continuity of the coal in uniform quality cannot be so safely estimated owing to the presence of thin laminæ of sand which are very variable in their extent and thickness. Over 100,000 tons are estimated as available at this extreme eastern end, to which some considerable additions may be made for a mile further westward, but the main area of presumed coal under the Ara plateau further west presents so many evidences of thinning out of the seams that it would be rash in the extreme to foretell anything regarding it until the test borings have been completed.

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of February, March and April 1893.

Substance.	For whom.	Result.
3 specimens of coal .	Finlay, Muir and Co., Calcutta.	Proximate analysis.

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of February, March and April 1893—continued.

SUBSTANCE.	For whom.	Result.
A specimen of iron ore (limonite) from Maha Champa Island, Mergui District.	P. N. Bose, Geological Survey of India.	Contains 36 8 per cent. of iron (Fe.).
A specimen of pyritous quartz, and 1 of aphanite with iron pyrites, from Chowk Pazat, Upper Burma.	Surgeon-Major Masani .	Assayed for gold.
	F. Nöetling, Geological Survey of India.	No. "1." A compact bluish green rock breaking with a semi-conchoidal fracture, studded with minute grains of magnetite, pyrites and pyrrhotite, the last two named minerals occurring also in irregular patches. Specific gravity : 2·86. Under the microscope the rock presents the characters of a volcanic agglomerate rather than an ordinary lava or a dyke rock. Fragments of plagioclase felspars, hornblende, and augite in all stages of decomposition are mixed with opaque grains of magnetite and pyrites in a microlithic groundmass. Only the occurrence in the field can decide exactly the origin of the rock, but from the microscope alone it seems like a compacted volcanic ash. It contains a trace of gold, but not enough for estimation. No. "2." A coarser-grained rock than No. "1" but presenting the characters also of a compact and altered agglomerate. There has been a considerable development of epidote at the expense of the decomposing felspathic materials which occur in large quantities. Fragments of amygdaloidal and site are occasionally found included and undergoing the general decomposition. Specific gravity 2·884. No. "3." Pyritous and felspathic quartz considerably weathered and stained with ferruginous matter. Yielded on assay 1 dwt, 7 grs. of gold per ton of material.

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of February, March, and April 1893—continued.

SUBSTANCE.	For whom.	Result.
		No. "4."
		Pyritous quartz yielded on assay 4 dwt., 14 grs. per ton of material.
		No. "5."
		An undoubted igneous rock of the aphanite group, being composed principally of lath-shaped plagioclase felspars, hornblende, and relics of augites with considerable quantities of granular magnetite. The whole rock has been considerably decomposed, epidote formed and veins of other decomposition products occurring.
		A sample of carbonate of lead also labelled "No. 5" evidently occurs associated with this rock, apparently in filling cracks. Fragments of rocks petrologically similar to "No. 5" occur mixed with the fragments of cerussite.
		On analysis it yielded 69·1 per cent. of lead and 33oz., 16 dwt., 4 grs. of silver to the ton of lead
		Large quantities of this material would therefore be exceedingly valuable as an ore of lead and silver.
		Nos "6," "7." and "8."
		Specimens of excellent coal They all show, compared with Indian coals, a very low percentage of ash, and fairly high proportion of fixed carbon. As fuels for steaming purposes they are far above the average of Indian coals, but the want of coking power detracts from their value as fuels for smelting purposes.
		The proximate analysis of the above are as follows:—
		No. "6."
		Quantity received . 4 lbs.
		Moisture . . . 7·68 Volatile matter . . 34·42 Fixed carbon . . 53·58 Ash . . . . 4·32 100·00
		Ash—light gray. Does not cake.

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of February, March and April 1893—concluded.

SUBSTANCE.	For whom.	Result.
		No. "7." Quantity received . . 11½ oz. Moisture . . . 6·60 Volatile matter . . 34·14 Fixed carbon . . 52·22 Ash . . . . 7·04 100·00 Ash—light reddish gray. Does not cake. No. "8." Quantity received . . 9¾ oz. Moisture . . . 8·28 Volatile matter . . 36·14 Fixed carbon . . 48·58 Ash . . . . 7·00 100·00 Ash—dirty gray. Does not cake. No. "9." A compact granitic looking rock, composed of quartz, plagioclase felspar, smaller quantities of orthoclase, hornblende passing into chlorite and magnetite. The quartz occurs in granular crystals, and some of it is secondary. In classification the rock may be placed between the granitites and quartz diorites. Specific gravity 2·70. No. "10." Decomposed steatic rock.
One specimen of coal, from Heinla Chang, Mergui District, Burma.	P. N. Bose, Geological Survey of India.	Quantity received . 5 lbs. Moisture . . . 16·40 Volatile matter . . 35·08 Fixed carbon . . 44·24 Ash . . . . 4·28 100·00 Ash—light buff. Cakes, bur not strongly.
A specimen of clay for determination.	Burn & Co., 7, Hastings Street.	Indurated pipe-clay with quartz fragments.

Notification by the Government of India during the months of February, March, and April 1893, published in the "Gazette of India," *Part I.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	REMARK.
Revenue and Agricultural Department	$\frac{813}{80}$, Surveys, dated 16th March 1893.	R. D. Oldham.	Furlough.	1st May 1893, or subsequent date.	...	...
Ditto .	$\frac{824}{71}$, Surveys, dated 16th March 1893.	Theo W. H. Hughes.	Ditto .	26th January 1893.	...	...

Notifications by the Government of India during the months of February, March, and April 1893, published in the "Gazette of India," *Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.*

Department.	No. of order and date.	Name of officer.	From	To	Nature of appointment, etc.	With effect from	REMARK.
Revenue and Agricultural Department.	$\frac{231}{72}$, Surveys, dated 26th April 1893.	T. H. D. La Touche.	Deputy Superintendent.	Officiating Superintendent.	Acting, temporary.	26th January 1893.	

Postal and Telegraphic Addresses of Officers.

Name of officer.	Postal address.	Nearest Telegraph Office.
T. W HUGHES	*On furlough.*	
C. L. GRIESBACH	Hindu Bagh (Baluchistan) .	Quetta.
R. D OLDHAM	Calcutta	Calcutta.
P. N. BOSE	" . . .	"
T. H. D. LA TOUCHE . . .	Haranpur . . .	Haranpur.
C. S. MIDDLEMISS . . .	Abbottabad . . .	Abbottabad.
T. H. HOLLAND . . .	Calcutta	Calcutta.
W. B. D. EDWARDS . . .	Quetta	Quetta.
F. H. SMITH	Rewa	Rewa
P. N. DATTA	Calcutta	Calcutta.
F. NOETLING	Wuntho	Wuntho.
HIRA LAL	Abbottabad . . .	Abbottabad.
KISHEN SINGH	Rewa	Rewa.

DONATIONS TO THE MUSEUM.

FROM 1ST FEBRUARY TO 30TH APRIL 1893.

18 specimens of minerals, consisting of Datholite on greenstone, from Bergen Hill, New Jersey; Colemanite with tabular Celestine, from San Bernardino Co., California; Bournonite, from Cornwall; Adamine, from Pamarisa, Laurium, Greece; Galena, from Alston, Cumberland; Topaz, from San Luis, Potosi, Mexico; Witherite with Bromlite, from Fallowfield Mine, Hexam, Northumberland; Anatase, from Binn, Wallis, Switzerland; Melanophlogite, from Girgenti, Sicily; Fluor, from Weardale, Durham; Dyserasite, from Andreasberg, Harz; Phenacite, from Mount Antero, Chaffee Co. Colorado; Chessylite, from Copper Queen Mine, Arizona; Rubellite, from California; Microcline, from Pike's Peak, Colorado; Calcite, from Bigrigg Mine, Egremont, Cumberland; Agate, from Uruguay, South America; and Barytes, from Buckingham Co., Virginia.

PRESENTED BY THE TRUSTEES OF THE BRITISH MUSEUM, LONDON.

Specimens of Bryozoa and Lamelli branches from a well 250 feet below the surface, Poozoondoung, Rangoon.

PRESENTED BY KRUGER & CO., RANGOON.

ADDITIONS TO THE LIBRARY.

FROM 1ST JANUARY TO 31ST MARCH 1893.

Titles of Books. *Donors.*

ALLEN, *Alfred H.*—Commercial Organic Analysis: a treatise on the properties, proximate analytical examination, and modes of assaying the various organic chemicals and products employed in the arts, manufactures medicines, etc, with concise method for the detection and determination of their impurities, adulterations, and products of decomposition, Vol. III, pt. 2. 8° London, 1892.

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CURZON, *George N.*—Persia and the Persian Question. Vols. I and II. 8° London, 1892.

DANA, *E. S.*—The System of Mineralogy. 6th Edition. 8° Loudon, 1892.

DEICHMÜLLER, *J. V.*—UEBER Gefässe mit Graphit-Maleri aus sächsischen Urnenfeldern. 8° Pam. Dresden, 1890. THE AUTHOR.

HATCH, *F. H.*—Text-Book of Petrology, containing a description of the rock-forming minerals and a synopsis of the chief types of igneous rocks. 8° London, 1892.

HÖFER, *Hans.*—Das Erdöl (Petroleum) und seine Verwandten. 8° Braunschweig, 1888.

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TOULA, *Prof. Dr. Frans.*—Neure Erfahrungen Über den Geognostischen Aufbau der, Erdoberfläche. 8° Pam. Wien, No date. THE AUTHOR.

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„ IX-X.—Burma, Parts, 1-2.
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PUNJAB.—Final Report of the Revised Settlement of the Jullundur District in the Punjab. By W. E. Purser, B. C. S. Flsc. Lahore, 1892.
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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1893. [August.

Geology *of the* Sherani Hills, by TOM D. LA TOUCHE, B.A., *Officiating Superintendent, Geological Survey of India.* (With Maps and Plates.)

The observations recorded in the present report were undertaken primarily for the purpose of examining the oil springs known to exist in the Sherani Hills, and determining whether the geological conditions were such as to hold out any prospect of there being any large accumulation of oil beneath the surface in the neighbourhood of the springs. They were almost entirely confined therefore to the region occupied by tertiary strata lying between the Takht-i-Suleiman and the plains of the Indus valley, forming only a small portion of the territory inhabited by the assemblage of clans known as the Sheranis. They did not extend beyond the Zao river on the north, and the Toi on the south, that is, they were comprised, roughly speaking, between the parallels of 31° 25′ and 31° 55′ N. Lat. These two rivers, taking their rise on the western slopes of the Takht range, flow through the hills in an easterly direction, and enter the plains of the Indus valley to the west of Dera Ismail Khan. In spite of the forbidding character of the gorges by which these rivers traverse the main range, no small amount of traffic is kept up along them, since many of the caravans, which yearly pass to and fro between Dera Ismail Khan and Khorasan, make use of them. All that has hitherto been known regarding the geology of this area has been confined to the immediate neighbourhood of these routes. It would hardly be safe, even now that the tribes have been brought under control, to wander about these hills in the manner that a geologist finds necessary to a due comprehension of the features of the ground, without a considerable escort, and it is only quite recently that a map of the country, sufficiently accurate to admit of the carrying out of a detailed geological survey, has been published.

Previous observers: MR. GRIESBACH, 1883.

The expedition of 1883, under General Kennedy, undertaken for the purpose of enabling Major Holdich, R.E., to carry out certain survey observations from the highest peaks of the Takht range, was accompanied by Mr. Griesbach as geologist. This expedition, both in going and returning, used the more northerly of the two routes above-mentioned, that by the Zao river. However convenient this route may have been for the main purposes of the expedition, it was not so satisfactory from a geological point of view, as regards the lower hills lying between the Takht and the plains; for not only is the section exposed along

the Zao much concealed by recent deposits of drift, but, as it happens, several of the formations to be found in the area to the south are quite unrepresented on that route. Moreover, the character of the inhabitants is such that Mr. Griesbach was unable to carry his observations to any distance from the line of march, without a special escort, which on account of the rapidity with which the expedition passed through this portion of the hills, could not be furnished to him. Mr. Griesbach's observations were included in his 'Report on the geology of the Takht-i-Suleiman.[1]

MR. OLDHAM, 1890.

In November 1890, the southern route, that by the Toi river, was taken by Mr. Oldham, who had joined the Khidarzai Field Force for the purpose of visiting the oil springs near Moghal Kot on that river. In this case also, the rapidity of the march prevented his doing anything in addition to the special object of his visit, beyond noting roughly the geological features observable immediately along the route followed.[2]

Present exploration.

It was not until the past field season was well advanced that I received orders to undertake a more detailed survey of the Sherani Hills, with especial reference to the question of developing the oil resources of the country. I was unable to leave Dera Ismail Khan till the end of February, and entered the hills on the 1st March, with an escort composed of sepoys of the 2nd Sikh Infantry, and a number of Sherani Border Police. The party was under the guidance of Sirdar Masud, an Afghan, Extra Assistant Commissioner in charge of the district, of whose kindness and forethought in supplying our needs, no easy matter in so desolate a country, I cannot speak too highly. Sub-Assistant Kishen Singh, of the Geological Survey, also accompanied me, and I found his knowledge of the geology of the hills further to the south, where he had recently been employed under Mr. Oldham, in Baluchistan, of the greatest value.

Entering the Sherani country by the Zam Chaudhwan, a narrow defile on the outer edge of the hills, by which the Toi river escapes into the plains to the south-west of Draban, we moved by easy stages up the river to Moghal Kot. Here I halted several days collecting samples of the oil, and making a plan and section of the locality. Afterwards leaving the Toi valley, we worked gradually northwards examining the valley of each of the larger streams, which all flow in a more or less easterly direction across the general strike of the rocks, and thus afford good sections, until we reached the Zao river. Thus I was able to compare my observations with those made by Messrs. Griesbach and Oldham. Finally we returned to the plains along the Zao river about the middle of April. The hot weather of 1892 will long be remembered in the Punjab as one of abnormally high temperature, even in the hills there was no exception to the prevailing heat, the thermometer standing at 100° in my tent so early as March 22nd. The barren and stony nature of the country in which there are few trees sufficiently large to afford shelter to even a small tent, added greatly to the discomfort attending such unlooked for heat.

PHYSICAL FEATURES.

Orography.

The area now dealt with forms a fringe of hilly ground, from 14 to 16 miles in width, at an average elevation of between two and three thousand feet above sea-level, extending from the plains of the Indus valley to the foot of the Takht range, under name which the Takht-i-Suleiman

[1] Records, G. S. I., Vol. XVII, Pt. 4, p. 175.

[2] Records, G. S. I., Vol. XXIV, Pt. 2, p. 83.

itself with the Kaisargarh, the Zao range to the north, and the mass of hills culminating in the peak called Mizri Koh to the south, are included for the purposes of this report, all these forming one mountain mass. As a rule the lower hills are disposed in a succession of parallel ridges, corresponding with the outcrops of the harder rock bands, and running in a north and south direction. Some of these ridges rise to a considerable height, notably one which runs parallel to the Takht about two miles to the east of it. This is composed of a hard band of sandstone and limestone and rises to perhaps 6,000 feet or more. It is partly shown, marked as of nummulitic age, in Mr. Griesbach's admirable sketch of the Takht-i-Suleiman.[1] From the western edge of the lower ground, the lofty mountain mass of the Takht range rises abruptly in a succession of bare rocky slopes and precipices, to an elevation of over 11,000 feet above the sea. Facing this at the outer edge of the hills is a belt of Siwalik rocks, very irregular in width and altitude, which forms a kind of rim to the broad trough of softer rocks lying between it and the Takht. This belt is about four miles wide on the Toi river, where it rises to an elevation of probably not less than 5,000 feet, but further north its width is reduced to a mile or less while its elevation is proportionately diminished. The survey made by Sheikh Mohiuddin in 1891 did not include this portion of the hills, and its topographical details are not given in the accompanying map.

Rivers.

The main drainage of the hills takes its rise on the western side of the Takht range. The principal rivers are the Toi which is joined at Domanda by a large tributary, the Shingao, also coming from the west side of the Takht; the Lohara which flows through the gorge called the 'Gut' and issues into the plains to the north of Draban, and the Zao, which issues near Zarkanni. All these rivers flow for several miles of the upper part of their course in a northerly direction, probably in every case following the bands of softer rock which underlie the massive cretaceous limestone forming the highest peaks, as observed by Mr. Griesbach in the case of the Upper Lohara valley.[2] Then they make an abrupt bend to the east, and cut directly through the range, even the hard massive limestone on the eastern flanks of it proving no insuperable bar to their passage. These gorges, locally called Dhanas, are of the most wild and gloomy description. From the water's edge on either hand perpendicular walls of rock rise to an elevation of several thousand feet, and in some cases approach so nearly that the sky over head is invisible from the stream. A sketch of one of these, the Zao defile, is given in Mr. Griesbach's report, and presents a good idea of their general characteristics.[3]

River gorges or Dhanas.

The gorge called the 'Gut' is perhaps the deepest and narrowest of these defiles. It passes through the highest portion of the range immediately beneath the Kaisargarh peak, and is almost impassable except on foot. It is difficult to believe that such stupendous gorges are due to the action of water alone, and this difficulty is enhanced by their resemblance to rifts in the hill sides. The term 'rift' indeed would be the most expressive that could be employed in describing them, if it did not imply a tearing asunder of the strata. That no such disruption of the

[1] Records, G. S. I., Vol. XVII, Pt. 4, pl. 1, b.
[2] Records, G. S. I., Vol. XVII, Pt. 4, p 184.
[3] Loc. cit., p. 176.

rocks has occurred is proved by the continuation of individual bands of rock across the bed of the stream, and by the absence of those irregularities in the gradient of the stream bed which we should expect to find if it were the result of a fissure.

The 'Tiri'.

Issuing from these gorges, the rivers enter a belt of ground from two to four miles wide, to which the name Tiri is locally given, and in which there are two conspicuous ridges running parallel with the Takht range. Of these the inner, nearest the main range, is composed of cretaceous limestones and shales, and the outer of hard sandstones and limestones of nummulitic age. To the north of the Shingao the inner ridge is suppressed, owing to the thinning out of the rocks composing it, before it reaches the Lohara. The outer ridge is suppressed in like manner, and probably from a similar cause to the north of the Lohara, and does not extend as far as the Zao, which, after emerging from the main range, traverses no high ground between it and the outer rim of Siwaliks.

Below the Tiri, the rivers enter upon a broad zone, occupied for the most part by soft shaly rocks, which have been greatly denuded by the drainage from the main range. A large part of this zone is covered by recent drifts, which form an even stony plain sloping very gradually towards the east. At first the river channels are well defined and narrow, enclosed between perpendicular walls of drift, rising to 300 feet or so above the water-level; but lower down the valleys become wider and the terraces on either side less distinct. The whole of the cultivation is carried on along the borders of the streams, often in the narrow spaces between them and the foot of the terraces. For although the level plains above would doubtless be fertile enough, if there were any means of bringing water on to them, works of such magnitude as would be necessary are apparently beyond the ability of the tribesmen. The minor streams, which join the main rivers in this part of their course, are usually waterless during a great portion of the year. Indeed, in the main streams themselves the water often disappears at various points, and flows underneath the shingle for considerable distances. Water springs unconnected with the large streams are of very rare occurrence; in fact, I only know of one of any size, namely, near China on the Shingao.

Of the gorges through the outer belt of Siwalik rocks, that of the Toi is by far the longest. This is known as the Zam Chaudhwan from the town of that name lying near its mouth, and is about seven miles long. The river flows in a zig-zag course between lofty perpendicular cliffs, formed of the inclined beds of Siwalik conglomerates and sandstones, occasionally running for some distance along the strike of the rocks, and then without any apparent cause, breaking directly across them. On the Lohara, as before mentioned, the Siwalik belt is much reduced in width, and the passage cut through it by the river, known as the Zam Drazand, can hardly be called a gorge. Further north again the Siwalik belt broadens out to some extent, and the Zao traverses it by a pass called the Sheikh Hydur, similar to the Zam Chaudhwan, but much shorter.

STRATIGRAPHICAL GEOLOGY.

Structure.

The geology of the Sherani Hills is by no means complicated. As a general rule the formations follow each other in a normal succession, the older being found to the west, and the newer to the east. In fact, the whole of the rocks form the eastern limb of a huge anticlinal, the axis of which runs along the Suleiman range itself, the general dip

being in an easterly direction. An exception to the prevailing easterly dip is found just within the fringing belt of Siwalik rocks, where what may be called a sporadic anticlinal occurs, the axis of which passes in a north and south direction through Domanda, parallel to the main anticlinal. Along this line disturbance has taken place at two distinct periods; first, after the deposition of the eocene rocks, which were upheaved, in places into a vertical position and greatly denuded, the overlying Siwaliks resting on their up-turned edges, and containing fragments derived from the nummulitic limestone; and secondly, after the deposition of the Siwaliks, which have been bent into a double fold, synclinal and anticlinal, denuded along the axis of the latter so as to expose the underlying lower tertiary rocks. This latter folding has been in some cases severe enough to bring the lower Siwalik beds also into a vertical position, and apparent parallelism with the nummulitic strata beneath, as at Domanda itself.

An hypothesis has lately been put forward by Mr. E. Reyer which appears to account satisfactorily for the frequent occurrence of such minor anticlinals as this, on the flanks of those greater folds to which mountain ranges are due. According to this theory, an abstract of which was published in 'Nature' of July 7th, 1892,[1] such folds are referred to a gliding down of the softer overlying strata, as the harder rocks beneath forming the core of the main range are upheaved. Without accepting this theory in its entirety, as an explanation of all folding, which would appear from his concluding remarks to be the author's contention, though it is difficult, of course, to form an opinion from a short abstract, yet given the upheaval of a mountain mass, such as the Suleiman range, it certainly does seem possible that minor folds on the flanks of it might be formed by such a "gliding" process, and the aspect of this narrow fold at Domanda lends considerable support to the theory. Besides this Domanda anticlinal, many other dislocations on a smaller scale, in some cases producing overfolds and faults, are to be seen, especially in the higher beds of the lower tertiaries, which might readily be explained on the same hypothesis. A conspicuous instance of one of these was noted on the Toi river between Parwara and Baskai villages (see Sketch, Pl. II).

Formations represented.

The formations represented in the Sherani Hills are given in the following table, in which I have included for comparison the succession found in the Mari country to the south, according to Mr. Oldham,[2] and by Mr. Blanford in the southern extension of the Suleiman range. [3]With those on the north as described by Messrs. Wynne and Griesbach, I have found no correlation possible of the kind that could be expressed in such a table as this. I have also omitted the cretaceous rocks below the massive limestone, the succession of which is given in Mr. Griesbach's paper on the geology of the Takht-i-Suleiman,[4] as these were not visited by me. In his report on the Safed Koh, Mr. Griesbach states that the sequence of the Mesozoic rocks, as observed in that area, closely resembles that in the Suleiman range.[5]

[1] "On the causes of the deformation of the Earth's Crust," 'Nature' No. 1184, Vol. XLVI, p. 224.

[2] Records, G. S. I., Vol. XXV, Pt. 1, p. 18 (Map).

[3] Memoirs, G. S. I., Vol. XX, Pt. 2, p. 34.

[4] Records, G. S. I., Vol. XVII, Pt. 4, p. 182.

[5] Records, G. S. I., Vol. XXV, Pt. 2, p. 88.

The rocks are given in descending order:—

Geological Age.	Sub-Divisions.	No. in Sections, see Pl. I.	Sherani Hills.	Approx. maximum thickness.	Mari Region, Baluchistan, Oldham	Approx thickness	Southern Sulaiman Range, Blanford.	Approx. thickness.
Recent and sub-recent.	Do.	15	Alluvium	?	Alluvium	?	Alluvium	?
			Fan deposits and Talus	...	Gravels, etc, sub-recent.	...	Gravels of slopes, etc.	
Pliocene	Siwalik, Upper	14	Conglomerates, sandstones, and clays.	?	Conglomerates, sandstones and clays.	?	Conglomerates, sandstones, and clays.	2,500
	Siwalik, Lower	13	Sandstones and clays. *Mammalian bones, etc.*	2,000			Sandstones, clays, bone beds, etc.	5,000
Miocene	Nari	—	Wanting	..	Wanting	...	Sandstones, clays, etc.	2,000
Eocene	Nummulitic. Upper	12	Olive shales and clays	2,000	Spintangi Group	1,000	Olive clays, shales, sandstones, etc., with a few thin bands of nummulitic limestone.	8,000
		11	Limestone with *nummulites.*	40				
		10	Olive shales *highly fossiliferous,* platy limestones at base.	1,500				
		9	Limestone crowded with *nummulites.*	14				
	Nummulitic. Middle	8	Shales with gypsum bands	550				
		7	Shales and sandstones, *unfossiliferous.*	10,000	Ghazij Group	3,000	Coarse brown sandstone with a band of limestone breccia.	1,000
	Nummulitic. Lower	6	Massive limestone band	250	? Dunghan Group*	2,000	? Hard whitish sandstone grit.	1,500
		5	Quartzose sandstone (oil locally).	1,000				
		4	Shales with minute *nummulites* and other fossils.	1,000				
Cretaceous	Belemnite beds	3	Thin bedded limestones with *belemnites.*	1,500	Belemnite beds	1,000		
		2	Black shales with *belemnites.*					
		1	Massive limestone with *corals, etc.*	5,000	Massive limestone	...	Dark grey limestone passing downward into limestone shales.	1,000 seen.

NOTE—Since the above table was drawn up, Mr. Oldham has informed me that he has come to the conclusion that the Dunghan Group is more likely to be cretaceous than eocene, in spite of the nummulites it contains.

I have not thought it necessary or advisable to give local names to the sub-divisions of the lower tertiary system in the Sherani Hills. For, although the area is an isolated one, it seems almost certain that further research will result in correlation of the more important groups on the south at any rate. It appears to me, therefore, better to wait until the intervening area has been examined, in order that a multiplicity of names for what may prove to be identical groups may be avoided.

DESCRIPTION OF THE SECTIONS.

Toi River Section (No. 1, Plate 1).

The most complete section of the rocks composing the Sherani Hills is to be found on the Toi river, which traverses the whole series in an oblique direction from south-west to north-east. I propose therefore to describe the section to be seen on this river in some detail, at the same time noting those points in which the sections found on the rivers further to the north differ from or resemble it.

CRETACEOUS.

1. Massive limestone.

This is the lowest rock seen in the area examined. On the Toi river it is of enormous thickness, and very homogeneous in texture, showing very few bedding planes. It is an intensely hard and compact limestone, almost black in colour, and emitting a slightly fetid odour when struck with the hammer. A few corals occur in it, and sections of gasteropod shells are visible on some of the smooth water worn rock faces in the gorge, but none of these could be extracted. Towards the summit of the range as observed by Mr. Griesbach, it becomes lighter in colour and contains more corals. In the Toi gorge, or Dhana, the rock dips at about 30° to the east, and as far as I ascended the gorge, about a mile and a half, nearly as far as the place marked Dhane Sar on the maps, no signs of its base were visible. The thickness of the limestone is therefore more than 4,000 feet. In the river gorges to the north it presents the same characters, but the dip increases until, at the Zao river, it is approximately vertical. About half a mile below the rock, called the Sar-i-Sang in that defile, there are some more shaly limestones with sandstones which appear to mark the base of the massive limestone. In these beds were found a *Rhynchonella* and a very doubtful fragment of an *Ammonite*. These may be the equivalents of the uppermost beds of Mr. Griesbach's group No. 4, the brown earthy beds, No. 5, of his section, being locally absent. The total thickness of the massive limestone in this section would therefore be something over 5,000 feet.

Belemnite beds.
2. Black shales.

The massive limestones are overlaid conformably by black shales containing *belemnites*, which are found loose on the surface of the ground, weathered out from the shales, but do not appear to be very common, except at certain horizons. They are followed by thin bedded bluish and greenish limestones interstratified with shales.

3. Thin bedded limestones and shales.

This series forms a conspicuous ridge parallel to the Takht and where cut through by the river the individual beds of limestone, averaging perhaps a foot in thickness, and of lighter colour than the bands of shale, are seen to preserve a very uniform thickness for great distances, giving a highly characteristic banded appearance to the cliffs. Near the top of the group the limestone bands become thicker

and whiter in colour; *Belemnites*, imbedded in the rock, and somewhat difficult of removal, are not uncommon in some of the beds. No *nummulites* were detected in any of these beds. In every particular this whole group, including the black shales at the base, corresponds with the 'Belemnite beds', overlying the massive cretaceous limestone of Baluchistan, referred to as variegated limestone shales by Mr. Blanford[1] and called at first 'Chapper Shales' by Mr. Oldham in his report of 1890,[2] a name which he afterwards abandoned in favour of the more generally applicable term 'Belemnite beds,'[3] and there can be no doubt that they are identical.[4]

Identical with Belemnite beds of Baluchistan.

On the Toi the thickness of the group is about 1,500 feet. To the north it is found in force on the Shingao river, but beyond this becomes gradually thinner, until on the Lohara, its thickness is reduced to about 200 feet, and further north, on the Zao it is entirely absent.

Northern extension of group.

Tertiary Rocks.

I could detect no traces of an unconformable break between this and the next succeeding system, there being a perfect parallelism of dip between them, but the existence of an interval of time between the deposition of the two is denoted by the occurrence, in the basement beds of the overlying system, of fragments derived from the cretaceous limestones These fragments appear to have come from the uppermost whitish limestone bands; at least none that could be referred to the darker massive limestones were detected, and so far it would not appear that it is necessary to imagine that any great interval of time is represented by this break. But, on the other hand, the great change in organic remains, for there is an entire disappearance of the *Belemnites*, accompanied by the appearance of *Nummulites* and other lower eocene fossils, would appear to denote the lapse of a considerable time. It is quite as difficult therefore to estimate the value of this break here, as Mr. Oldham found it in Baluchistan, where the relations of the lowest eocene with the underlying cretaceous beds correspond exactly with those observed by me in the Sherani Hills, except that in the Dunghan group, or lowest tertiaries, Mr. Oldham found in certain localities an admixture of cretaceous with tertiary forms.[5]

No unconformity.

Lower Nummulitic.

Resting with perfect conformity of dip, as before stated, upon the cretaceous limestones, comes a thick series of shales, light olive green in colour, with numerous bands of sandstone, some of which are fossiliferous.

4. Shales with sandstone bands.

Near the village of Kharghwazha (No. 5 on map), Kishen Singh found, in a band of rather coarse sandstone, numerous remains of *Gasteropods*, and minute *Nummuli-*

[1] Memoirs, G. S. I., Vol. XX, Pt. 2, pp. 37, 83.
[2] Records, G. S. I., Vol. XXIII, Pt. 3, p. 93.
[3] Records, G. S. I., Vol. XXV, Pt. 1, p. 19.
[4] When visiting the Chapper rift, last April, I found more than one specimen of *Belemnite*, in the beds exposed in the rift, quite similar to those collected in the Sherani Hills.
[5] Records, G. S. I., Vol. XXV, Pt. 1, p. 22.

tes are not uncommon in some of the finer grained sandstones. These fossils have not yet been properly examined, but so far as could be seen from a cursory inspection of them, there are here no signs of that abnormal mixture of tertiary with cretaceous forms noticed by Mr. Oldham in Baluchistan. Unfortunately the number of the 'Records' containing Mr. Oldham's paper did not reach me till after I had left this section on the Toi, so that my attention was not directed to the importance of a rigorous search for such forms, but it was so close that I cannot think that if such fossils as *Ammonites*, *Echinoconidæ*, etc., had been present, they would have escaped our notice.

5. Quartzose sandstones.

The shales are succeeded by a band of hard quartzose sandstones, reaching a thickness of nearly 1,000 feet, bluish white in colour and weathering to a warm brown. They are generally thin bedded, and contain thin bands of shale, some of which are carbonaceous enough to have given rise to reports of coal occurring on the Toi river. None of them, however, are of any economic importance. It is near the base of these sandstones that the oil springs of Moghal Kot occur, concerning which, and the probability or otherwise of there being a large accumulation of oil in the neighbourhoood, I have submitted a separate report.[1] Fossils, mostly sections of bivalves, occur sparingly in the sandstone beds at the base, and near the top is a band containing an abundance of oysters (?*Exogyra*).

6. Thick limestone band.

Resting upon the sandstones is a cap of massive and very hard grey limestone about 250 feet thick. No recognisable fossils of any size were found in this band, but portions of it are crowded with what appear to be sections of a Foraminifer, perhaps an *Alveolina*; but the sections, which are all that can be seen on the surface of the rock, are so much distorted that I could not determine their nature with accuracy. This limestone band with the sandstone beneath it forms a lofty serrated ridge, rising with a long even slope of about 30° corresponding with the dip from the lower ground to the east, and precipitously scarped on the west, facing the Takht range.

Northern extension of Lower Nummulitic group.

In the three river gorges to the north of the Toi, the various sub-divisions of this group, as observed in that river, are present in full force, and the ridge formed of the two upper members can be traced continuously across the country between them. But between the Lohara and Zao rivers this ridge comes to an abrupt end, and with it all signs of the quartzose sandstones and overlying limestone disappear. The lowest member is represented on the Zao by a great thickness of black shales, in which no fossils were found, passing downwards into lighter coloured splintery shales, much contorted and crushed, and resting directly upon the massive limestones of the main range, the Belemnite beds also having disappeared. It is impossible on this section to fix with accuracy any division between the lower and middle nummulitic groups, owing to the absence of the limestone band which affords a convenient boundary line in the southern sections, marking as it does, an abrupt change of conditions in the deposition of the strata. What the reason may be for the disappearance of two so well-marked bands of hard rock can only be conjectured. That it is not due to any form of dislocation, I am pretty certain, for in the Zao river, only two miles or so to the north of the end of the ridge, a complete section of the rocks is exposed, and though there is a small double fold in the sand-

[1] Records, G. S. I., Vol. XXV, Pt. 4, p. 171.

stone and shales (see Section No. 3), there is no faulting of such magnitude as would account for the entire disappearance of these two bands. I am inclined therefore to think that the feature is an original one, and that the disappearance of these beds is caused by their sudden thinning out due to an abrupt shallowing of the basin of deposition to the north. This hypothesis is borne out to some extent by the highly carbonaceous character of the strata belonging to this group exposed in the Zao river, pointing to the existence of a land surface at no great distance to the north.

MIDDLE NUMMULITIC.

7. Shales with sandstone bands. Unfossiliferous.

Next in order, resting conformably upon the limestone band, follows a great thickness, probably not less than nine or ten thousand feet of shales and sandstones, in the greater portion of which no organic remains are found, beyond a few carbonaceous markings, which may be obscure plant impressions, and a few insignificant strings of coal. A band of nummulitic limestone was found near the top of this group between Parwara and Baskai on the Toi, but the ground was so obscured by talus that it was impossible to say that this band had not been brought into its present position by folding, and really belonged to the next higher group. Near the base greenish and red shales and clays are most conspicuous, interstratified higher up with bands of soft grey sandstone, weathering red, and sometimes coarse gritty bands showing false bedding. The whole aspect of the group recalls that of the Murree beds of the North-Western Himalayas, but its position beneath a group containing several bands of highly nummuliferous limestone precludes its being referred to the same period. On the other hand it agrees in position and appearance, and in the occurrence in it of carbonaceous traces, with the Ghazij group of Baluchistan, in which the workable seams on the Sind-Peshin Railway occur, and in all probability it is represented in the southern extension of the Suleiman range by the eocene sandstones containing coal, in the country of the Luni Pathans, as described by Mr. Ball.[1]

UPPER NUMMULITIC.

No stratigraphical break.

There is no stratigraphical break of any kind between the foregoing group of shales and sandstones and the overlying group of upper nummulitic rocks, the greater portion of which is also shaly The only reason for drawing a line of division here is the evidence of a return to more distinctly marine conditions afforded by the presence of bands of limestone, containing nummulites and abundant remains of other organisms, in the upper group of beds. The change is marked by the appearance of a series of rocks very persistent in character, which is found wherever the base of the upper group is exposed.

8. Shales with gypsum bands.

This series is characterised by the presence of numerous bands of saccharoid gypsum, and of grey limestone, in which gypsum occurs closely mingled with the limestone, and sometimes in cavities. In the latter case the weathering away of the limestone from the rounded masses of less easily dissolved pure white gypsum gives the surface of the rock a peculiar appearance, as though it were studded with

[1] Records, G. S. I., Vol. VII, Pt. 4, p. 153.

snowballs. Mr. Oldham records a similar association of gypsum with fossiliferous limestone in Baluchistan, and notes the difficulty of accounting for their presence together.[1] The shales interstratified with the gypsum are of very vivid colours, green, red, and purple predominating, differing in this respect from the shales accompanying the gypsum in Mr. Oldham's Spintangi group. A section of these rocks measured by Kishen Singh near the village of Zor Shahr on the Lohara, is as follows:—

In descending Order.

		Ft.	Ins.
Dip N. 80° E @ 23°	Nummulitic limestone, soft and shaly, greenish in colour, and full of nummulites (No. 9 in sections)	14	0
	Green shales	60	0
	Gypsum	7	3
	Green shales	3	3
	Gypsum	3	6
	Green shales	3	0
	Gypsum	1	6
	Limestone	1	0
	Green shales with a calcareous band	12	0
	Calcareous sandy band	1	3
	Green shales with a limestone band	22	6
	Gypsum	3	0
	Green shales	6	6
	Gypsum	0	3
	Limestone	0	9
	Green shales	7	0
	Gypsum	3	6
	Green shales	14	0
	Gypsum	5	3
	Green shales	28	0
	Gypsum	11	7
	Dark green shales	0	6
	Gypsum	2	0
Not well seen	Green shales	8	0
	Gypsum	2	0
	Green and purple shales with 3 layers 8 inches to 1 foot thick of gypsum	55	0
	Gypsum	1	0
	Green shales with purple bands	50	0
	Grey limestone with gypsum in cavities	2	2
	White limestone	0	11
	Green shales with marly layers	49	0
	Purple shales with thin gypsum bands	19	0
	Gypsum	2	10
	Red shales with 1 foot 6 inches marly layer in middle and thin gypsum bands	13	0
	Sandy argillaceous band	2	9
	Green shales with sandy bands at top	24	0
	Foliated gypsum	6	2
	Green shales with red bands	16	0
	Limestone with gypsum in cavities	4	0
	Red and green shales with thin sandstone layers	101	0
Dip N. 80° E @ 20°	Greenish sandstones		
	TOTAL	568	11

[1] Records, G. S. I., Vol. XXIII, Pt. 3, p. 98.

This band of gypsum-bearing rocks can be traced continuously from the Toi to the Zao ıiver, and extends to an unknown distance both to the north and to the south. It was apparently found by Mr. Blanford in about the same position far to the south, west of Dera Ghazi Khan It is also exposed along the axis of the Domanda anticlinal, on the Toi at Domanda itself, and on the Lohara just within the fringing belt of Siwaliks but is concealed on the Zao by the unconformable overlap of the latter rocks.

9. Nummulitic limestone band.

This band of rock, although insignificant in thickness, is remarkable not only on account of its composition, but also for the very wide area over which it extends, without any change in character. It is a greyish limestone, slightly tinged with green, entirely made up of the remains of *Nummulites*, apparently belonging to a single species, crowded together in the utmost profusion throughout the whole thickness of the band. Wherever I have measured it, at widely separated localities, the band has an almost uniform thickness of 14 feet. It forms the crest of a well marked ridge, the scarped face of which is composed of the underlying shales with gypsum, and is found wherever that formation is present. It is interesting to conjecture what the conditions may have been under which this peculiar band of rock was formed. The great thickness of unfossiliferous beds beneath points to the existence of a gradually shallowing basin, by the desiccation of which the gypsum beds were formed. Then a subsidence of the surface accompanied by the irruption of salt water brought in conditions favourable to the growth of the nummulites, exceedingly uniform over a very large area. These conditions appear to have ceased as suddenly as they began, for the nummulitic band is followed by thin bedded, fine grained, platy limestones, in which I found no nummulites whatever.

Platy limestone.

These latter rocks range from 30 to 40 feet in thickness and are usually light grey in colour, but on the Toi between Parwara and Baskai they are of a dense black colour, weathering white and occasionally contain nodules of chert. They generally form a dip slope on the reverse face of the ridges, at the crest of which the nummulitic band, above referred to, is found.

10. Olive shales, highly fossiliferous.

The limestones are followed by a band of olive shales in which fossils are exceedingly numerous. These are mostly casts, and have not yet been examined. There is no great variety of species but a great profusion of certain forms, a large *Cardita* being very common among the bivalves, also an *Ostrea* with V-shaped markings, Gasteropods, *Cerithium* and *Turritella*, are also found in great numbeıs. The thickness of this band of shales is about 1,500 feet.

11. Limestone band with nummulites.

This band of limestone having olive shales both above and beneath it, crops out as a more or less conspicuous ridge, parallel to and at a fairly uniform distance from, the ridge formed by the lower limestones belonging to this group. *Nummulites*, which appear to belong to a different species from those in the lower band, are sparingly distributed through the rock, and a few specimens of echinoderms and corals, also a somewhat mutilated carapace of a crab, were obtained from it. The minor dislocations which the strata have undergone are well exhibited by this band of limestone, especially in the valleys of the Toi and its tributaries above Parwara, where it is

repeated at least twice by a folding (see Sketch Pl. II). The thickness of this limestone band is not great, 30 or 40 feet, but in common with the other members of this upper group, it is persistent over a very large area.

12. Olive shales.

It is followed by a thick band of olive shales, closely resembling lithologically band No. 10, but almost barren of fossils. This band is about 2,000 feet thick on the Toi, and although of little interest occupies the greater portion of the area covered by the Upper Nummulitic group.

Correlation of Upper Nummulitic group.

I have little hesitation in identifying this group with Mr. Oldham's Spintangi group in Baluchistan, as described in his report on the country adjoining the Sind-Peshin Railway.[1] Although there are differences of detail in the various rock beds comprising the group It is worthy of remark that 'Olive shales' are of almost universal occurrence in the upper portion of the Eocene division over the whole area occupied by these rocks in the North-Western Himalayas, Sind, and Baluchistan.

Unconformable break.

It is difficult to estimate the value of the break which took place between the deposition of the Nummulitics and Siwaliks. The entire discordance in dip between the Siwaliks and underlying nummulitic rocks, as seen in the Zao river sections (see Section No. 3, Pl. I), would seem to imply the lapse of a considerable amount of time. But the Siwaliks on the Zao belong to the uppermost part of that series, whereas a few miles to the south on the Toi, we find some thousands of feet of sandstones and clays interposed between the Upper Siwaliks and the Nummulitics; and here there is not the same evidence of unconformity. In fact, where the formations have been least disturbed, for instance, in the synclinal west of Domanda, the lowest beds of the Siwaliks rest with apparently complete conformity on the Upper Nummulitics. Too much stress should not be laid, I think, upon the discordance in dip seen on the Zao. The disturbance of the beds beneath, to which it is due, was confined to quite a narrow zone, and need not have taken any very considerable length of time to accomplish. The probability is that this period was one of considerable changes of level in closely adjoining areas, so that upheaval and denudation were proceeding in certain areas, while not far off deposition was going on. This is indicated by the fact that fragments of the limestone beds belonging to the Nummulitic series are found imbedded in the lower Siwalik strata. There occurs a band of gritty sandstone in the latter rocks, some way up from the base, between Domanda and Landai on the Shingao, crowded with broken *Nummulites*.

13. Lower Siwaliks.

Although the lower Siwalik rocks attain a considerable thickness, probably not less than 2,000 feet on the Toi and its tributary the Shingao, they are entirely absent on the Lohara and Zao rivers to the north. How far this suppression is due to the unconformable overlap of the Upper Siwaliks, it is impossible to say, but it seems probable that it partly at any rate arises from original irregularity in the deposition of this formation. In lithological characters it resembles in all respects the formation of the same age, both to the south, in Sind and Baluchistan, and to the north in the Punjab. The prevailing rocks are rather soft grey 'pepper and salt' sandstones, interstratified with clays and shales of bright colours, usually red and orange.

[1] Records, G. S. I., Vol. XXIII, Pt. 3, p. 96.

Occasionally bands of coarse sandstone are met with, but conglomerates, such as characterise the Upper Siwaliks, never occur in these lower rocks. The surface of some of the finer sandstone beds are covered with ripple marks. A fine example of this is to be seen a short distance below the village of Paiwara, where the sloping surface of a low ridge, through which the river breaks at right angles, is covered with it for several hundred yards. A sandstone band in about the same position on the Shingao, about six miles to the north, also displays the same structure.

Organic remains.

In a somewhat pebbly band near the base of the Siwaliks on the road from Paiwara to Landai, Sub-Assistant Kishen Singh was fortunate enough to discover a few fragments of mammalian or reptilian bones, and of teeth, probably reptilian. The bones were found about two miles to the south-east of Landai, and the teeth at two localities, one about three quarters of a mile from Parwara, the other about two and a half miles from the same village. The position of these fossils agrees perfectly with that of similar remains, found by Captain Vicary in the Bugti Hills, and by Mr. Blanford in the southern Suleiman range, in rocks belonging to the same subdivision, and afford a further proof if any were needed as to their identity.[1] From another bed, of green calcareous shale, among these lowest Siwaliks, but at a lower horizon than the beds containing the bones and teeth according to Kishen Singh, a few fragmentary specimens of a strongly ribbed bivalve were collected, which, although not perfect enough to be identified with certainty, belong, I suspect, to one of the species of ribbed *Unios* found by Mr. Blanford to the south, and by Mr. Wynne to the north, associated with the mammalian and reptilian remains.[2]

Distribution of Lower Siwaliks.

On the Toi the rocks belonging to this group form an open synclinal above the confluence with the Shingao, the axis of which runs north and south, and bend over to the east of the Domanda anticlinal, where they are tilted up vertically. Lower down the river the dip becomes easterly, at a high angle, and the rocks disappear conformably beneath the conglomerates and sandstones of the Upper Siwaliks. To the north the synclinal flattens out and is replaced on the Zao by a low anticlinal (see Section No 3 Pl. I), which may partly account for the disappearance of the lower Siwalik rocks in that direction, they having been removed by denudation. To the south Mr. Blanford found a synclinal in these rocks in the same position as on the Toi, and it is probable that they extend continuously from the Sherani Hills into the area examined by him.[3]

14. Upper Siwaliks.

This formation occurs everywhere along the margin of the area examined, forming a lofty range with a gentle dip slope running up from the Indus plain on the east and scarped on the western side, where its precipices overlook the lower ground stretching toward the Takht-i-Suleiman, occupied by the eocene shales and limestones. It is made up, as everywhere else, of thick beds of conglomerate and sandstone, regularly interstratified. The greater proportion of the pebbles forming the conglomerate appear to have been derived from the hard cretaceous limestone, but pebbles of sandstone, probably from the same group, are also common. The thickness of this formation varies

[1] Memoirs G. S. I., Vol. XX., Pt. 2, pp. 21, 57.

[2] Records, G. S. I., Vol. X, Pt. 3, p. 120.

[3] Mem. G. S. I., Vol. XX, Pt. 2, p. 120.

considerably, being greatest on the Toi river, which has cut a deep gorge through these beds. On the Lohara and Zao, the uppermost beds alone seem to be represented, resting with total unconformity on the Upper Nummulitics.

Breccias near Zor Shahr, ? of Siwalik age.

To this period may possibly belong a thick mass of limestone breccia, forming the summit of a hill about three miles to the west south-west of Zor Shahr. The sandstones and shales of the middle nummulitic series, on which it rests, dip steadily in an easterly direction at a high angle, but no bedding planes are to be seen in the breccia which forms a precipitous scarp, some two to three hundred feet in height. A similar cap, but of smaller extent, is to be seen resting on the top of the ridge formed by the limestone and gypsum bands at the base of the Upper Nummulitic series (Nos. 8 and 9 in Sections) east of Ragha Sar, but I was not able to visit this. The material of the outlier near Zor Shahr appears to have been derived from the hard band of limestone. No. 6, at the top of the Lower Nummulitics, and is perhaps a portion of an ancient talus formed at the foot of the high ridge composed of that rock. The breccia, I am certain, belongs to an older period than the terrace deposits of the river valleys, and may quite possibly date back to Upper Siwalik times.

Comparison with Geology of known areas to North and South.

1. Southern area.

Both to the north and south of the portion of the Suleiman range now described, a considerable gap occurs, of the geology of which little or nothing is known. On the south the survey of the range was carried by Mr. Blanford in 1882 as far as the parallel of 30° 30′ N. Lat., or some 100 miles to the south of the Sherani Hills. At the northern limits of Mr. Blanford's survey the aspect of the tertiary rocks appears to correspond very closely with that of the rocks belonging to the same period found further north, there being a great development of shales and sandstones in the Eocene division, as compared with the sections still further to the south.[1] These rocks also occupy a large portion of the area to the west of the main range traversed by Mr. Ball.[2] Mr. Blanford notes the occurrence of a section on the Charchar Pass[3] of a thin band of limestone intercalated in the olive shales which form the topmost sub-division of the Eocene, and forming a low continuous ridge running north and south, beneath which there are several beds of white gypsum. This band also appears in several streams to the north,[4] and probably corresponds to the band characterised by gypsum layers (No. 8) at the base of the Upper Nummulitics in the Sherani hills. Again, near the northern limits of the area, on the Sangarh stream, a thick band of limestone appears in the middle of the Eocene system,[5] forming a distinct and well marked ridge continuing for a long distance to the north, and known as the 'White Range.' This is possibly the equivalent of the thick band of limestone, forming the top of the lower division of the Eocene in the Sherani hills (No. 6), and immediately overlying the sandstones in which the Moghal Kot oil occurs, where it also forms a conspicuous ridge.

(1) Memoirs, G. S. I., Vol. XX, Pt. 2, pp. 44, 109, 112.
(2) Records, G. S. I., Vol VII, Pt. 4, p. 153.
(3) Memoirs, G. S. I., Vol. XX, Pt. 2, p. 109.
(4) Loc. Cit., pp. 112 to 121.
(5) Loc. Cit., p. 122.

The uppermost beds of the cretaceous series in the southern area were found by Mr. Blanford to consist of hard white sandstones, forming the core of the main range.[1] If these are, as Mr. Griesbach suggests, the equivalents of his group No. 4,[2] the massive limestones and Belemnite beds must be entirely absent in the southern area, a supposition difficult to accept in regard to their great development within so short a distance to the north, and their occurrence also within no very great distance to the west in the country between Thal Chotiali and the Sind-Peshin Railway. It is equally difficult to suppose that the cretaceous limestone and Belemnite beds have been removed by denudation in the southern extension of the Suleiman range, for in that case we should expect to find conspicuous traces of unconformity between the Eocene and cretaceous rocks there, whereas Mr. Blanford distinctly states that all the formations exposed in that section, from Upper Siwaliks to cretaceous limestone shales, are conformable.[3] It seems more reasonable to suppose that the white sandstones observed by Mr. Blanford are, if cretaceous, of local occurrence only, and are not represented at all in the Sherani hills. No fossils were found in them, and Mr. Blanford's reason for placing them in the cretaceous system was the occurrence immediately above them of a band of limestone breccia, which he supposed to mark the base of the Eocene. But, in a recent paper Mr. Oldham takes the 'limestone breccia' as marking the division between the Ghazij and Dunghan groups, [4] the latter of which, from the character of its fossils, holds a doubtful position between secondary and tertiary, though, as he points out, Mr. Blanford considered it to be nummulitic, and he discusses the contradiction involved. The difficulty, however, does not affect the present argument, for whether the Dunghan group is cretaceous or eocene, or intermediate between the two, I should be inclined to consider the white sandstones as the equivalents of that group, which is subject, as Mr. Oldham observes, to abrupt changes of character, rather than to imagine so great a discontinuity of deposition, or such an enormous amount of denudation unaccompanied by any unconformity, as would be necessary to account for their being the equivalents of Mr. Griesbach's Takht-i-Suleiman sandstones.

There is a decided similarity between the physical features of the northernmost part of the area described by Mr. Blanford and of the Sherani Hills. The great anticlinal which forms the main range, and has resulted in the upheaval of the enormous mass of the Takht-i-Suleiman, is continued into the southern area, but it becomes much flattened in that direction, and moreover appears to be divided up into several rolls, so that the tertiary rocks may be traced continuously from the east across the crest of the range to the west. On the east of the main range Mr. Blanford notes the appearance north of Sakhi Sarwar (west of Dera Ghazi Khan) of a double roll in the uppermost tertiaries, a synclinal on the west nearer the main range, followed by an anticlinal to the east. This feature I found to be distinctly represented on the Toi and Shingao rivers in the Sherani hills.

More recently a large tract of country, adjoining and partly included in the area described by Mr Blanford, and lying to the west of the main range, at a distance of about 150 miles to the south-south-east of that now described, has been geologically mapped in detail by Sub-Assistants Kishen Singh and Hira Lal, under the

(1) Memoirs, G. S. I., Vol. XX, Pt. 2, pp. 43, 113, 123.
(2) Records, G. S. I., Vol. XVII, Pt. 4, p. 185.
(3) Memoirs, G. S. I., Vol. XX, Pt. 2, p. 44.
(4) Records, G. S. I., Vol. XXV, Pt. 1, p. 22.

direction of Mr. Oldham, whose report was published in Part. I of the 'Records' for the present year.[1] In a previous paper, published in the 'Records' for 1890,[2] Mr. Oldham had also described the formations existing in that region. The similarity between the various sub-divisions of the tertiary system, as determined by Mr. Oldham, and those observed by me in the Sherani Hills is most striking, and I have little hesitation in correlating the sub-divisions with those named by him, I have no doubt that when the intervening tract of country comes to be surveyed, it will be found possible to trace these sub-divisions from one area into the other. Kishen Singh was able to recognise several features in the composition and disposition of the formations corresponding to those with which he was familiar in the area to the south, and his knowledge of them was of great assistance to me. After leaving the Sherani Hills, I had an opportunity of paying a flying visit to a part of the area surveyed by Mr. Oldham, bordering on the Sind-Pishin Railway, and what I saw there tended to confirm my view as to the general identity of the formations in the two areas.

2. Northern area.

To the north of the Sherani Hills occurs another considerable gap, occupied by the Waziri Hills, regarding the geology of which we have very little knowledge. On comparing the geology of the tertiary rocks in the districts lying beyond this gap, as described by Messrs. Wynne and Griesbach, with those of the same age in the Sherani country, we find that they have little in common, and it is evident that great changes must occur in the interval.

Several considerations tend to show that the Lower Tertiary formations in these hills are more intimately connected with those found in the regions to the south, than with those on the north. Indeed it appears quite possible that a barrier existed in the area now occupied by the Waziri Hills, from later cretaceous to Siwalik times, between the basin of deposition of the Suleiman range, and that of the Safed Koh and North-West Punjab. In support of this hypothesis may be adduced the thinning out of the more distinctly marine beds, the limestones, in the uppermost cretaceous and Lower Eocene formations towards the north in the Sherani Hills. Also the gradual extinction of the Miocene Nari beds in the same direction. In the Sheikh Budin hills, which are clearly visible to the north-east from the Takht-i-Suleiman, Mr. Wynne found that the Eocene nummulitic rocks were entirely absent, and the cretaceous very poorly represented, (3) but that they are found increasing in thickness towards the north-east, in the direction of the Maidan range. Again to the north of the Waziri hills, on the section between Kushalgarh and Thal on the Kurram river Wynne found the Eocene limestones gradually disappearing in a westward direction, (4) while in the Salt Range and North-West Punjab that formation is almost entirely composed of limestone. The Murree group also, so highly developed in the North-West Punjab, was found to become gradually thinner in the same direction. Mr. Griesbach has pointed out that elevation had taken place in the hill area on the north-west frontier in Miocene times. (5) Considering the discordance in strike between the rocks composing the Suleiman range and the Safed Koh with their skirting

(1) Records, G. S. I., Vol. XXV, Pt. 1, p. 18.
(2) Id. Vol. XXIII, Pt. 3, p. 93.
(3) Memoirs, G. S. I., Vol. XVII, Pt. 2, pp. 74, 91.
(4) Records, G. S. I., Vol. XII, Pt. 2, p. 113.
(5) Id. Vol. XXV, Pt. 2, p. 66.

ranges, the former striking due north and south, while the latter strikes east and west, notwithstanding the fact that the upheaval of each of these great ranges was to a certain extent contemporaneous, it does not seem unlikely that in the angle between them the disturbance, which culminated in the production of the two ranges, should have been more intense, and perhaps dates back to a more remote period. An indication of intense disturbance in this region is afforded by the discovery by Mr. Wynne of an outburst of volcanic action to the west of Thal on the Kurram river,(1) whereby beds of Subathu aspect have been greatly altered. The observations of Drs. Stewart and Verchere, comprising the little we know of the geology of the Waziri country, point in the same direction, since they note the occurrence of metamorphic rocks in that district. In the Sherani country itself there is evidence of greater crushing of the strata as we proceed from south to north. The cretaceous rocks which slope at an angle of about 30° to the east in the gorge of the Toi become vertical in the Zao defile, while signs of intense crushing of the supra cretaceous rocks on the latter river are more conspicuous than to the south.

The question cannot be decided until the unexplored area between the Suleiman and Safed Koh ranges is examined, a task that will doubtless be of great difficulty, but of still greater interest geologically, for it is not often that two ranges agreeing so closely in their period of upheaval, but differing so entirely as regards the direction in which the forces that caused the upheaval were exerted, are found approaching each other so nearly. There is little immediate prospect of this examination being carried out, for it is likely to be many years before the Waziris are brought sufficiently under control to allow of an observer moving about in their country with the freedom which will doubtless be necessary to unravel so complicated a piece of geology.

Later Tertiaries.

With regard to the deposits of later tertiary age, the information now obtained from the Sherani Hills supplies a fresh link connecting the Siwalik rocks of the North-Western Himalayas with those of Baluchistan and Sind. The resemblance of the two divisions of the system in the former area with those found to the north and south is complete, both in their lithological aspect and in the occurrence of those mammalian and other organic remains so characteristic of the system.

SUB-RECENT DEPOSITS.

Terrace drifts (See Pl IV).

A few words must be given to the remarkable deposits of river gravels and boulder drifts with which a very large part of the area occupied by the Lower Tertiaries is covered, although drifts of the same character are so universally found at the foot of the hills surrounding the northern boundary of the Indian plains that it would require a far wider knowledge of them than I possess to do justice to the subject. These drifts form an even plain with a very gradual slope from west to east, only broken by the deep, often vertical-sided ravines, cut into it by the rivers of the present day. The ravines are excavated to a very uniform depth of about 300 feet below the upper surface of the terraces, but except near the mouths of the gorges which break through the hard ridges near the main range, the whole

(1) Records, G. S. I., Vol. XII, Pt. 2, p. 111

of this depth has not been excavated in the drifts alone, but has been carried down into the rocks beneath, forming the original floor of the valleys in which the drifts were deposited. Thus as we descend the rivers, we find this ancient floor, which is concealed, even in the river beds, higher up, gradually rising to a greater and greater elevation above the present river level, the capping of drift at the same time becoming thinner and thinner. This is well seen on the Toi, where at Moghal Kot the drifts are fully 300 feet thick, forming a vertical wall on either side of the river, whereas opposite Parwara they are reduced to 50 feet or less, although their upper surface is about the same height above the river as at Moghal Kot. From this it would appear that the inclination of the ancient valley floor was less than that of the present river, and yet the size of many of the boulders included in the drift, as compared with the shingle now moved by the rider indicates that the fall of the river in former times cannot have been less, and was probably greater than it is now. If this be the case, it follows that since the deposition of the drifts, there has been a gradual tilting of the ground in a direction parallel to the folding that took place after the deposition of the Siwaliks. It is possible that the earlier folding may have partly determined the position in which the drifts were deposited, but the coarseness of the material of which they are composed appears to require that the flow of water in former times was greater than it is now, and that a great change of climate has taken place in these regions. In some instances the drift terraces extend upwards into the gorges cut through the main range, as in the Zao defile (see sketch in Mr. Griesbach's report, Figure 5), (1) and they are very conspicuous in the 'Tiri' or belt of country between the main range and the lofty ridge of Lower Tertiary rocks facing it (see Plate V).

Evidences of recent elevation.

ECONOMIC GEOLOGY.

The only mineral of practical importance found in the Sherani Hills is the petroleum which occurs in small quantities near the village of Moghal Kot on the Toi river, where it oozes at several points from the thick band of quartzose sandstone near the top of the Lower Nummulitics, and is collected from shallow pits dug in the sand on the river bank at water level. The oil is of excellent quality, as determined by analysis made by Mr. Holland in the laboratory of the Geological Survey, but does not occur in sufficient quantity under present conditions to be of commercial value. I have already pointed out that it is possible that the flow may be increased to some extent by borings, but that the geological conditions are not such as to lead us to expect that a large accumulation of oil can be tapped within a reasonable depth from the surface.

Mineral oil.

Before leaving Dera Ismail Khan for the hills I was informed by the Deputy Commissioner that some of the military officers who had visited the hills had reported the existence of coal on the river Toi near Moghal Kot, and Mr. Griesbach also mentions the report of coal being found in the same locality, "in the neighbourhood of the Dana pass," *i.e.*, the Chuakhel Dhana.(2) In the gorge above Moghal Kot, in which the oil springs

Coal.

(1) Records, G. S. I., Vol. XVII, Pt. 2, p. 183.
(2) Records, G. S. I, Vol XVII., Pt. 4, p. 188.

occur, there are certainly some bands of carbonaceous shale, which I have marked in the section of that gorge attached to my report on the oil, but these are of no value whatever. In the middle nummulitic sandstones also there are occasional thin strings of coal, but no seams, nor did I discover or hear of any in the whole area examined by me.

Gypsum.

There is an unlimited supply of gypsum in the basement beds of the upper group of Nummulitics. In the section at Zor Shahr given at page 87, there are twelve beds of this mineral one foot thick or more, with a total thickness of 50 feet. But gypsum is of such common occurrence in the more settled districts, both to the north and south, that its existence in the Sherani Hills cannot be said to possess any practical importance at present.

Sulphur.

Traces of sulphur were observed in the upper Nummulitic rocks near Domanda, apparently derived from the decomposition of iron pyrites, but I could not discover that it occurs any where in sufficient quantity to enable the people of the country to make use of it as they do in the hills west of Dera Ghazi Khan, where sulphur is found and worked in several localities, as described in Mr. Blanford's Memoir. (1)

Carboniferous Fossils *from* Tenasserim: *by* FRITZ NOETLING, Ph. D. F.G.S., *Palæontologist, Geological Survey of India* (with a plate).

The first information about the occurrence of a fauna of carboniferous age in Tenasserim was given by Dr. T. Oldham in his "Notes on the Coal-fields and Tin-Stone Deposits of the Tenasserim Province."[2] A fauna consisting of corals, gastropods, brachiopods, crustacea was found in a series of sandstones, and grey shaly beds over these sandstones. This is, however, all that is known about this carboniferous fauna except a few remarks by Mr. Theobald,[3] merely stating that a few fossils had been found at Zwah-ga-byn, a limestone hill near Moulmein.

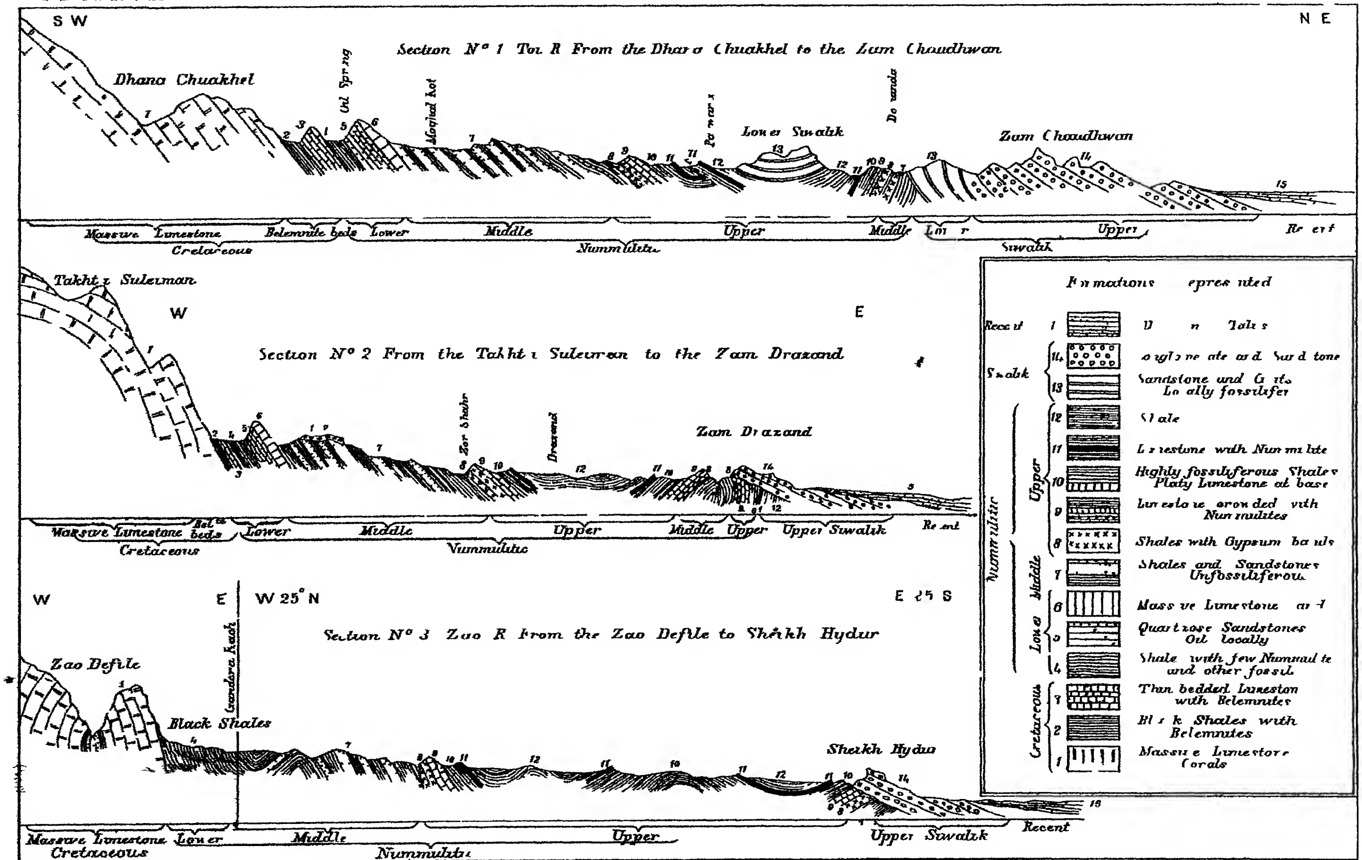
It is, however, not known what has become of the fossils mentioned by these gentlemen. They are not in the collection of the Geological Survey of India, and they were certainly never described in detail.

Under these circumstances it is most satisfactory that Mr. Bose has lately obtained a small series from the limestone hills near Therabwin in Tenasserim, which though rather ill-preserved is sufficient to decide definitely the question of the age of the Moulmein group. The fossils were found weathered and sticking out on the surface of a hard dark limestone, having apparently undergone a partial silicification. This mode of preservation has been most fatal to the finer structure of the foraminifera and corals, it being nearly entirely destroyed. There still remain, however, such characteristics as are sufficient for determination. As regards the

[1] Memoirs, G. S. I, Vol. XX, Pt. 2, p. 126.

[2] Records of the Government of India, Home Department, No. X, 1856; reprinted in Papers on Burma, page 375.

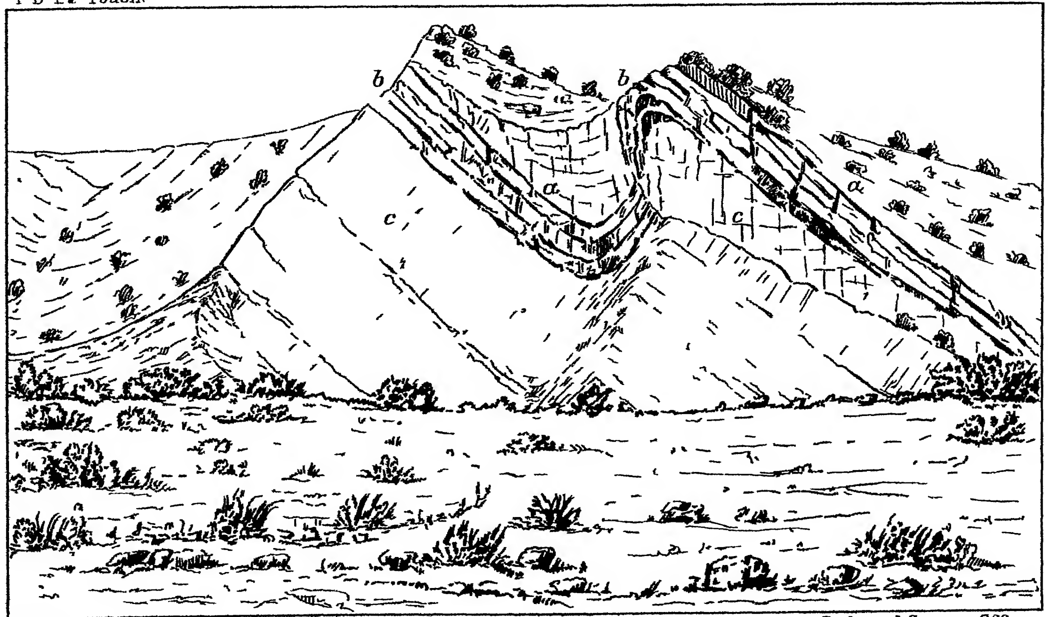
[3] On the Geology of Pegu, Memoirs, Geol. Surv. of India, Vol. X.


S W
N E
Section No. 1 Toi R. From the Dhana Chuakhel to the Zam Chaudhwan
Dhana Chuakhel
Uil Spring
Moghal kot
Lower Siwalik
Zam Chaudhwan
Massive Limestone
Belemnite beds
Lower
Middle
Upper
Cretaceous
Nummulitic
Siwalik
Takht i Suleiman
W
E
Section No. 2 From the Takht i Suleiman to the Zam Drazand
Zor Shahr
Drazand
Zam Drazand
Massive Limestone
Bel. beds
Lower
Middle
Upper
Upper Siwalik
Recent
Cretaceous
Nummulitic
W
E
W 25° N
E 25 S
Section No. 3 Zao R. From the Zao Defile to Shaikh Hydur
Zao Defile
Black Shales
Gandera Kach
Shaikh Hydur
Massive Limestone
Lower
Middle
Upper
Upper Siwalik
Recent
Cretaceous
Nummulitic
Formations represented
Recent
Siwalik
Nummulitic
Upper
Middle
Lower
Cretaceous
Sandstone and Grits Locally fossilifer
Limestone with Nummulite
Highly fossiliferous Shales Platy Limestone at base
Shales with Gypsum bands
Shales and Sandstones Unfossiliferous
Quartzose Sandstones Oil locally
Shale with few Nummulite and other fossil
Thin bedded Limestone with Belemnites
Shales with Belemnites

GEOLOGICAL SURVEY OF INDIA

T. D. La Touche

Records Vol XXVI Pt 3 Pl II



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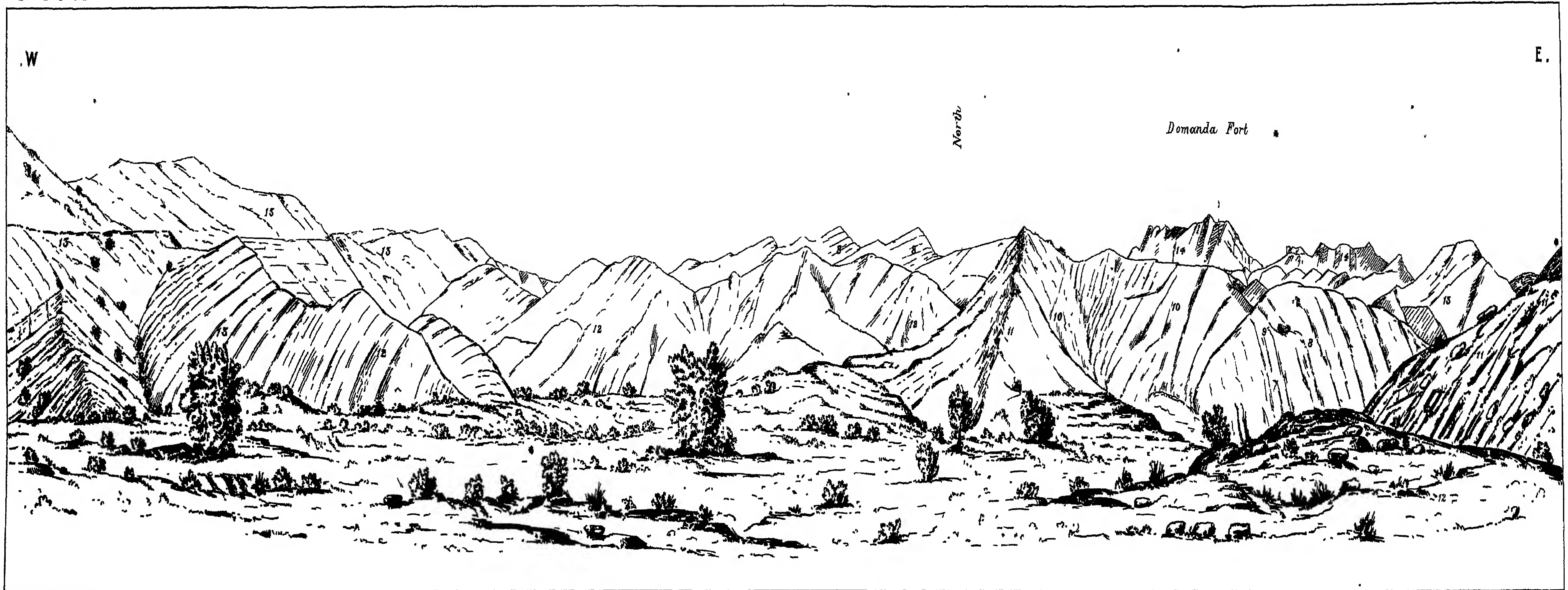
FOLD IN UPPER NUMMULITIC GROUP BETWEEN PARWARA AND BASKAI

a a Upper Olive Shales, No. 12 b b Limestone band No. 11 c c Lower Olive Shales No. 10



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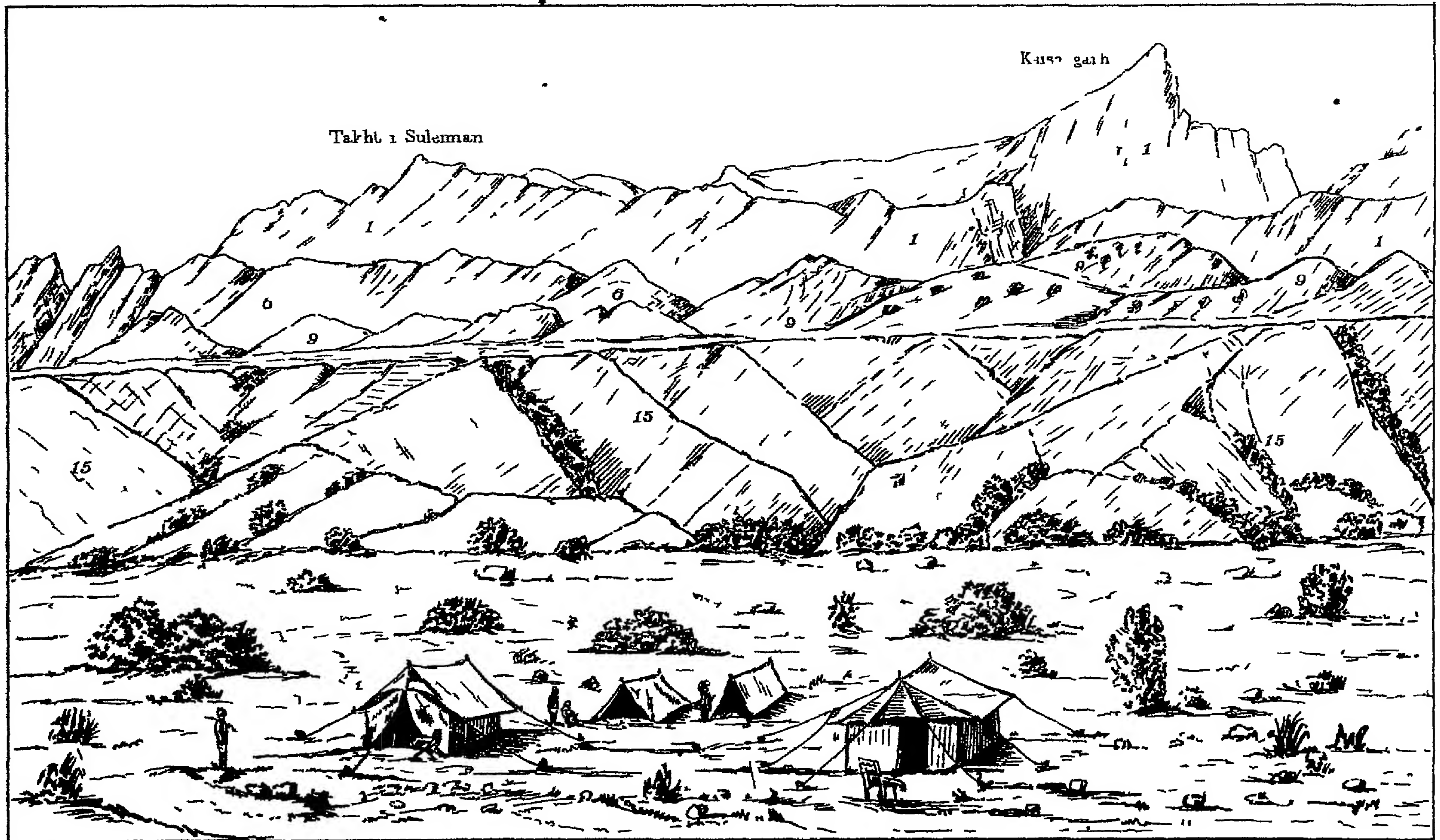
UPPER NUMMULITIC GROUP ON THE TOI RIVER NEAR DOMANDA.

8 Gypsum beds 9 Limestone band 10 Fossiliferous Olive shales 11 Limestone band 12 Olive Shales 13 Lower Siwalik 14 Upper Siwalik

T D La Touche



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THE TAKHT-I-SULEIMAN FROM THE ZAO RIVER

1 Massive Cretaceous Limestone 6 Lr Nummulitic Limestone 9 Ridge at base of Upp Nummulitics 15 Terrace drifts

graplad & Printed a

TERRACES IN THE TIRI CHUAKHEL, TAKHT-I-SULEIMAN IN THE DISTANCE

Geological Survey

brachiopods and gastropods, they are so badly damaged that their specific identity cannot be established; in one case, however—that of *Productus cf. sumatrensis*—there is still a sufficient number of characteristics visible to say that the Burma species is closely related to either *Prod. sumatrensis*, F. Roemer, or *Prod. sub-costatus*, Waag. and Wentzel.

As according to Dr. Oldham's division, the limestone series is younger than the sandstone series, the fauna from Therabwin must be of younger age than that mentioned by Mr. Oldham, though probably of the same age as that from Zwah-gabyn hill. The following species have been distinguished :—

1 Schwagerina oldhami, spec. nov.
2 Lonsdaleia salinaria, Waag. and Wentz.
3 Lithostrotion, spec. nov.
4 Aræpora cf. ramosa, Waag and Wentz.
5 Polypora cf. biarmica, Keyserl.
6 Productus cf. sumatrensis, F. Roemer.
7 Athyris, sp.
8 Spirifer, sp
9 Bellerophon, sp.
10 Pleurotomaria aff. durga, Waagen.
11 Murchisonia, sp,

So far as any conclusions may be drawn from the above species the chief interest lies in the fact of the association of Indian forms with those known from Sumatra. The genus *Schwagerina* does not occur in the Salt Range, but it is very common in the carboniferous limestone of Sumatra: on the other hand, the characteristic form of *Londsdaleia salinaria* from the middle productus limestone (Salt Range) is represented amongst the Burma fossils, while apparently a new form is represented by *Lithostrotion, sp.* As regards the *Productus* described as *cf. sumatrensis*, it is difficult to say, owing to the state of preservation, whether it represents the Sumatran species or that of the Salt Range, or whether it takes altogether an intermediate place. For reasons stated in the description, I think it to be closer allied to *Prod. sumatrensis*. The remainder of the fossils calls for no special remarks. The fauna may therefore be said to represent one in which Indian and Sumatran types are mixed; thus forming the connecting link between both areas. This is not astonishing; in fact it might have have been expected *à priori*: considering that Therabwin in Tenasserim is, in a straight line, only about 500 miles from the coast of Sumatra, while it is more than four times the distance from the Salt Range; one might in fact have expected a smaller number of Indian forms. I have no doubt that, once the Tenasserim carboniferous fauna is represented by more and better preserved specimens, it will be found that it bears a closer affinity to the Sumatran than to the Indian carboniferous strata.

Regarding the age, the fauna seems to tend to the upper carboniferous period.

Schwagerina oldhami, spec. nov. Pl. fig. 1, 1*a*.

This form is the most common species among the fossils from Therabwin, and although it is never well preserved the examination of a large number of specimens affords sufficient reason for establishing a new species. As already stated, it is impossible to arrive at an exact information as to the internal structure because subcrystalline infiltrations have largely obscured it.

The average size full-grown specimen has a diameter of 5 mm., and is about 3 mm. in thickness. In lateral aspect the full-grown specimens are therefore flat elliptical, while the younger ones are globular. The depressions marking the longitudinal septa are well marked and nearly evenly distanced, but they do not extend to the edge of the shell, where a smooth well-defined space remains.

Schwagerina oldhami is closely related to *Schwagerina verbeeki, Gein. sp.*, but the latter is easily distinguished by the more globular shape of full-grown specimens while the smooth keel on the edge of the shell is also absent.

Lonsdaleia salinaria, Waagen and Wentzel. Pl. fig. 2.

1886. *Lonsdaleia salinaria*, Waagen and Wentzel, Palæont. Indic., Series XIII, Salt Range Fossils. Productus Limestone Fossils, IV, 2, page 895, pl. C., figs. 1, 3, 4.

The only specimen shows distinctly the specific characters as described by Waagen. The corallum, an irregular-shaped mass, is astræiform, corallites prismatic five to seven-sided. The columella is strongly projecting. The secondary wall is exceedingly well developed, but in thin sections the septa are seen to extend uninterruptedly from near the columella to the outer wall of the calices, and there is no distinct peripheral vesicular zone.

Lithostrotion. sp. nov. Pl. fig 3.

One of the most frequent species is a form which undoubtedly belongs to this genus. It generally occurs in large fasciculate masses, the corallites are tall, and some reach up to 26 mm. in diameter; they are cylindrical and slightly flexuous, frequently cemented together, without, however, affecting the general circular section. The epitheca is thin, the striae always well marked, calices deep and irregularly circular. The columella is rather thick and round; the septa thin and slightly curved; there are plenty of interseptal vesicles.

The species from Tenasserim closely resembles *Lithostrotion affine*, Ret., but it seems that it is generally larger. Milne-Ewards[1] states that *L. affine* is the largest of all fasciculate Lithostrotions, except *L. canadense*, which is, however, easily distinguished by the shape of the corallites. As the Burma species is undoubtedly larger than *L. affine* it probably represents a new species, to decide which more material is, however, required.

Aræpora cf. ramosa, Waagen and Wentzel. Pl. fig. 4.

1886. *Aræpora ramosa*, Waagen and Wentzel, Palæont. Indic., Series XIII, Salt Range Fossils. Productus Limestone Fossils, IV, 2, page 839, pl. CVI, fig. 8-9.

There are several fragments of a massive, arborescent corallum, apparently parts of the branches, which are composed of numerous cylindrical or polygonal corallites, radiating from an imaginary longitudinal axis. The surface is still partly covered with rather small calices, of irregular round shape, but very ill-preserved. Internal structure entirely destroyed. The chief characters by which the specimen from Burma differs from the Indian type, seem to be that the corallites are generally thinner and the calices smaller. The specimens are, however, not sufficient to allow for the establishment of a new species.

[1] British Fossil Corals, page 200.

Polypora cf. biarmica, Keyserling.

1886. *Polypora cf. biarmica*, Waagen, Palæont. Indic., Series XIII, Salt Range Fossils Productus Limestone Fossils, IV, 2, page 791, pl. XC, figs. 5, 6, 7.

There are a few fragments of a Bryozoon that might be referred to the above species; as far as its characters can be observed, it agrees fairly well with Waagen's figure of the above species, but, of course, only more and better preserved specimens will decide the question.

Athyris, sp.

A small brachiopod, the larger part of which is still imbedded in the rock, might be referred to the above genus. The apical angle is a little above 90°; the beak thick and depressed. The surface is covered with fine radial ribs, which occasionally bifurcate; these are crossed by not very numerous but strong striæ of growth, which are on both valves well marked. These characters are insufficient for a specific determination, but it undoubtedly belongs to the group of *Athyris royssii*, Leo.

Spirifer, sp.

A small ill-preserved dorsal valve might perhap belong to this genus.

Productus cf. sumatrensis, F. Rœmer. Pl. fig. 4, 4*a*.

1880. *Productus sumatrensis*, F. Rœmer, Ueber eine Kohlenkalk fauna der Westkueste von Sumatra. Palæntographica, Vol. XXVII, page 5, pl. I, figs. 4*a* and 4*b*.

This single specimen of a Productus is too ill-preserved to allow of an absolutely correct definition. From the sculpture of the valves it is, however, quite certain that is closely related to either *Productus subcostatus*, Waagen, or to *Productus sumatrensis*, F. Rœmer. Waagen states that for a long time he himself considered *Prod. subcostatus* identical with *Prod. sumatrensis*, but he eventually came to the conclusion that the Indian species must be different from that of Sumatra, and therefore receive a new name. Now the main difference between *Prod. subcostatus* and *Prod. sumatrensis* consists in the presence of long and strong spines scattered over the whole surface of the ventral valve, and three or four deep grooves on each side of the dorsal valve which correspond to the strong spines on the other valve in the first species. The Burma specimen is unfortunately too fragmentary to allow of the examination of such delicate differences. There is only the dorsal valve open to examination, and of the ventral valve only a small part can be seen; besides being badly damaged on both sides. The sculpture consists of strong radial ribs, broader than their interstices, which are crossed near the apex by a system of concentric folds in the ventral valve, and a similar structure in the dorsal valve, except that the concentric folds extend as far as the visceral part of the valve. No traces of spines being noticed on the dorsal valve, I am inclined to compare this specimen with *Prod. sumatrensis* rather than with *Prod. subcostatus*.

Pleurotomaria sp. aff. durga, Waagen.

Pleurotomaria durga, Waagen, Palæont. Indic., Series XIII, Salt Range Fossils. Productus Limestone Fossils, IV, 2, page 119, pl. X, fig. 1.

A small, depressed, conical shell, consisting of about four whorls: seems closely related to the above species. There seem to be three principal ridges on the last whorl, between which fine thread-like ribs are observable. The specimen is altogether too badly preserved to allow of any exact determination.

Bellerophon, sp. Pl., fig. 5, 5*a*.

There are four specimens of one or perhaps two species of Bellerophon, which are, however, so badly preserved that a specific determination is impossible.

The larger specimen measures 44 mm. in diameter: the height from the top of the preceding to the bottom of the last whorl being 32 mm. No surface sculpture is traceable, but the species is remarkable for a deep though narrow umbilicus which was certainly not closed. Amongst the Salt Range species I cannot find any resembling this one as regards the deep and open umbilicus, and as *Bellerophon asiaticus*, Rom., is not sufficiently described and figured I am unable to say how far the Burma species is related to that of Sumatra.

Three smaller specimens resemble the big one by the deep umbilicus; no surface sculpture noticeable. These are probably only young individuals.

EXPLANATION OF PLATE.

Fig. 1. *Schwagerina oldhami, spec nov.*
Fig. 1*a*.—*b*. *Ditto* *ditto* double natural size.
Fig. 2 *Lonsdaelia salinaria*, Waag and Went.
Fig. 3. *Lithostrotion, spec. nov.*
Fig. 3*a*. *Ditto* *ditto*.
Fig 4 and 4*a*. *Productus sumatrensis*, F. Rœmer
Fig 5 and 5*a*. *Bellerophon*, sp.

On a deep Boring *at* Chandernagore. *by* R. D. OLDHAM, A.R.S.M., *Superintendent, Geological Survey of India.*

Through the courtesy of M. Aubrey Lecomte, Administrateur Principal of Chandernagore, I have been favoured with a detailed section and very fine series of specimens of the beds passed through in a boring sunk at that town in the hopes of finding water. The experiment has now been abandoned, and it is consequently desirable that the detailed section should be put on record It is accordingly printed here *verbatim* as received, the only addition being the insertion of the total depths to the bottom of each stratum and the equivalent of the metres in feet.

The section requires but little comment. The bed No. 13 is evidently the equivalent of the peat bed found near Calcutta at depths of from 30 to 35 feet; No. 32 is peculiar as containing numerous sub-angular fragments of felspar which must have been derived from some exposure of gneiss, a granite in the neghbourhood, which has since been covered up by alluvium owing to the subsidence which has taken place in the Gangetic delta; the specimen also contains a fragment of bone, apparently, of a turtle, converted into oxide of iron.

Fig 3

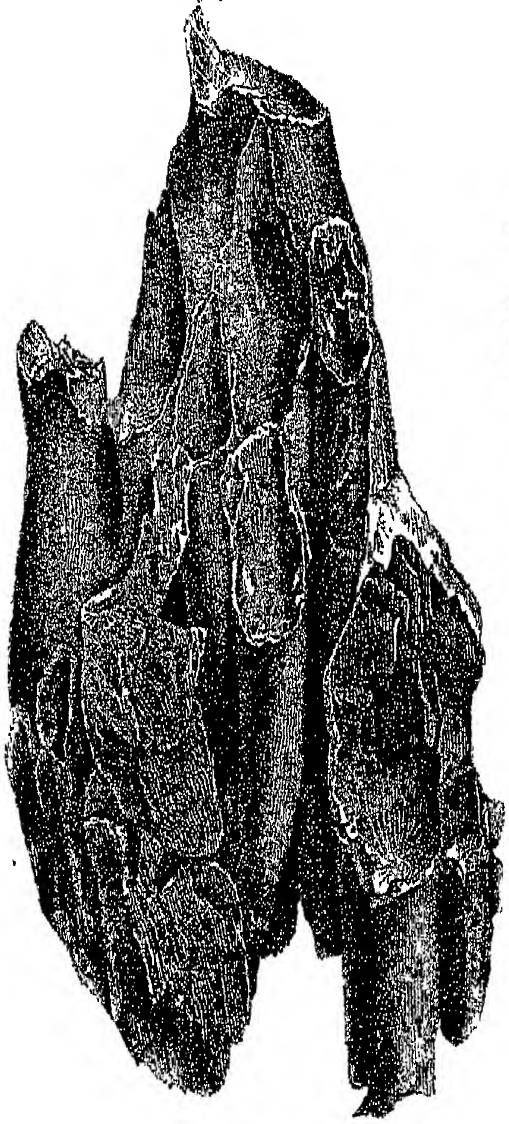

Fig 3 a

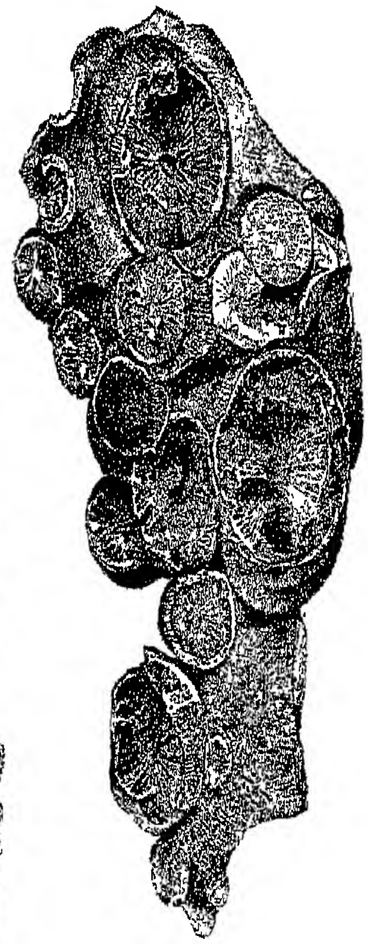

Fig 4

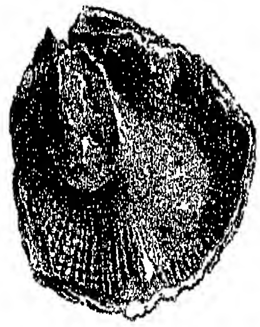

Fig. 4 a

Fig 2.

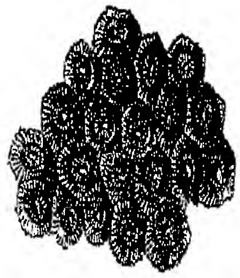

Fig. 1.

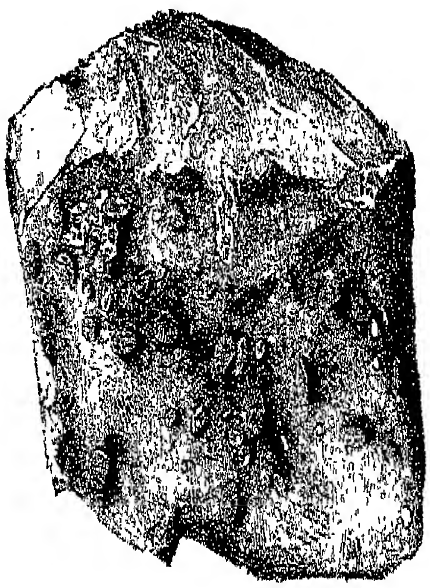

Fig 1 a

Fig. 1. b

Fig 5 a

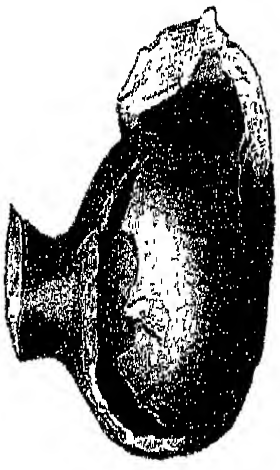

Fig. 5

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CARBONIFEROUS FOSSILS, TENASSERIM.

Tableau indiquant le nombre et la nature des couches rencontrées pendant le forage des puits artesien de Chandernagor.

			Thickness.	Depth.	Thickness.	Depth.
			Metres.		Feet.	
No.	1.	Terre végétale	0·80		2·62	
„	2.	Sable fin micacé d'un blanc sale mêlé de coquilles et de nodules calcaires	1·35	2·15	4·42	7 05
„	3.	Sable fin micacé d'un blanc jaunâtre mêlé légèrement de nodules calcaires	0·45	2 60	1·47	8·52
„	4.	Sable fin micacé d'un jaune rougeâtre	0·25	2 85	·82	9 34
„	5.	Sable fin micacé d'un blanc jaunâtre .	0·30	3 15	·98	10·32
„	6.	Sable fin micacé d'un gris cendré .	0·60	3·75	1·97	12 29
„	7.	Argile sableuse d'un gris foncé .	0·35	4·10	1·15	13·44
„	8.	Argile grisâtre mêlée de débris de coquilles et de nodules calcaires .	0·65	4·75	2·14	15 58
„	9.	Argile d'un noir grisâtre . .	2 50	7·25	8·21	23·79
„	10.	Sable fin micacé grisâtre . . .	1·40	8 65	4·59	28·38
„	11.	Argile noire plastique mêlée légèrement de concrétions ferrugineuses .	0·54	9·19	1·77	30·15
„	12.	Argile noir stratifié mêlée légèrement de bois pourris	0·65	9·84	2·13	32 28
„	13.	Tourbe	2·36	12·20	7·75	40 03
„	14.	Argile gris-noir mêlé de toutes petites concrétions ferrugineuses . .	1·66	13·86	5·44	45·47
„	15.	Argile grise mêlée de petites concrétions calcaires	1·00	14·86	3 28	48·75
„	16.	Argile colorée en jaune et noir mêlée de concrétions calcaires . .	1 90	16·76	6·23	54·98
„	17.	Argile micacée colorée légèrement en jaune par du carbonate de fer .	2·10	18 86	6·90	61 88
„	18.	Argile d'un jaune pale mêlée de nodules calcaires et souillée légèrement de carbonate de fer . .	2·29	21·15	7·51	69 39
„	19.	Argile bleuâtre tachée en jaune par du carbonate de fer	0·40	21·55	1·31	70·70
„	20.	Argile jaunâtre mêlée de concrétions calcaires	2·25	23·80	7·38	78 08
„	21.	Argile bleuâtre colorée en rouge et en jaune par du péroxyde de fer et de carbonate de fer . . .	0·95	24 75	3·12	81·20
„	22.	Argile colorée en jaune par du carbonate de fer	8·38	33·13	27·50	108·70

		Thicknes.	Depth.	Thicknes.	Depth.
		Metres.		Feet.	
No. 23.	Argile sableuse mêlée de graviers .	0.55	33·68	1·80	110·50
" 24.	Argile d'un gris pale colorée en jaune par du carbonate de fer et mêlée de nodules ferrugineuses . . .	4·60	38·28	15·10	125·50
" 25.	Argile d'un jaune sale micacée stratifiée colorée en jaune par du carbonate de fer	1·15	39·43	3·77	129·37
" 26.	Argile d'un blanc sale micacée .	1·55	40·98	5·09	134·46
" 27.	Argile sableuse micacée souillée d'oxyde de fer	0·55	41·53	1·80	136·26
" 28.	Argile colorée en jaune par du carbonate de fer	1·03	42·56	3·37	139 63
" 29.	Ocre jaune	3·40	45·96	11·16	150 79
" 30.	Sable argileux micacé mêlé de nodules ferrugineuses	0·90	46 86	2·95	153 74
" 31.	Sable argileux micacé souillé d' oxyde de fer	1·35	48 21	4·44	158 18
" 32.	Sable moyen et fin micacé mêlé de pétrification cailloux anguleux nodules ferrugineuses. . . .	24·30	72·51	79·81	237·99
" 33.	Sable fin micacé grisâtre . .	1·46	73·97	4·79	242·78
" 34.	Sable moyen micacé d'un blanc grisâtre	?	...	..	...

Note *on* Granite *in the districts of* Tavoy *and* Mergui, *by* P. N. Bose, B Sc., (Lond.), F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a plate).

The occurrence of granite in the districts of Tavoy and Mergui has an economic importance owing to the usual restriction of tin-ore in its vicinity. It is mainly met with in, though it does not entirely form three parallel ranges running in a general north-south direction. The easternmost of these ranges runs along or close to the boundary between Siam and the districts mentioned above, forming a well-marked watershed, the rivers on the Siam side flowing into the Gulf of Siam, and those on the Burma side running into the Mergui Archipelago. In this range, granite is known to occur at the following places:—

1. Renong, east of the Pakchan river.
2. The head waters of the Lenya and of the Little Tenasserim rivers.

Fig 1

Fig 2

3. The Siam frontier, east of the town of Tenasserim.
4. Parts of the Siam frontier in the district of Tavoy.

The middle one of the three ranges mentioned above forms the western boundary of the Pakchan, the Lenya, and the Tenasserim valleys. In it, granite has been noted at the following localities: —

1. Victoria Point—southernmost extremity of the district of Mergui.
2. Maliwun.
3. Sangái Bále (west of Namnwe).
4. Chaungtanang.
5. Inner Bokpyn.
6. North-west and south-west of Tenasserim.
7. Sixteen miles west of Tavoy, on the way to the Siamese frontier.

In the western range, granite has been found to occur in the southern part of the Henzai basin at a place called Oblingwin and at Maungmagan ten miles north-west of Tavoy. In the district of Mergui, the continuity of this range has been interrupted by submergence. But portions of it are to be met with in some of the islands of the Mergui Archipelago, as, for instance, the King's island, west of Mergui, and Silver island, west of Bokpyn.

The intrusive character of the granite was clearly observed at various places. Schists, the result evidently of contact-metamorphism, were found in contact with it at Maliwun and several other places. On an island west of Bokpyn in the Mergui district which is called Silver island, from the abundance of silvery white mica in the granite occurring there, small branching veins of it were found penetrating through micaceous schists. The junction is well seen here. Close to it the micaceous schist has lost its schistosity and has developed in it numerous crystals of tourmaline which are relatively very large at the line of junction (Pl. fig. 1). A sample from Chungtanang, some distance south of Bokpyn, shows similar junction. Here, however, the tourmaline crystals are not specially well developed at the line of junction (Pl. fig. 2). The intrusion of the granite appears to have affected the adjacent rocks for some distance; and several outcrops of phyllites and slaty rocks in its vicinity (as at Maliwun and Victoria Point), which the season before last I took on a hurried examination to belong to the transition series, appear to me now in the light of what I saw last season, to belong probably to the Moulmein Group which is of carboniferous age. About four miles west of the village of Tenasserim (between that place and Marton) I encountered some slaty rocks of a distinctly transitional aspect. They are within two miles or so of a great mass of granite; and though, owing to absence of good sections, they could not be satisfactorily brought into relation with the less altered members of the adjacent Moulmein Group, it appeared to me highly probable that they belong to it, and that their greater metamorphism was due to contact action.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 16.—ENDING 31ST JULY 1893.

Director's Office, Calcutta, 31st July 1893.

All the officers of the Survey are now in recess, their field work having gradually come to a close during the last three months. Mr. Superintendent R. D. Oldham left India on fifteen months' furlough on the 18th July 1893, and Dr. Noetling availed himself of privilege leave on the 15th idem.

The most important feature of our progress has been in the literary work of the department, as signalized by the completion of the second edition of the Manual of the Geology of India, by Mr. R. D. Oldham. As stated in the Prefatory Notice of this new edition:

> In the beginning of 1887 my predecessor, Mr. Medlicott, wrote as follows in his Annual Report of the Geological Survey:—"The two first parts of the Manual of the Geology of India, issued in 1879, have been out of print for some time, and the question of re-writing it has been much upon my mind. Parts of it would require abridgment, leaving local information to be sought for in the special Memoirs; and parts of it would need alteration and addition in view of extended information. The greater part of the two volumes was written by Mr. Blanford, who was for the time relieved of other work. To re-write the whole while carrying on the manifold current duties of the Survey has been more than I could attempt in India with any justice to either."
>
> The directing of the Survey since Mr. Medlicott's retirement is even fuller of current duties, not the least of which has been a considerably increased system of frequent tours over the length and breadth of the land; so that, however pressing it may also have been on my mind, I have been unable even to venture on the elaboration of a revised form of Messrs. Medlicott and Blanford's most excellent work; and I therefore gladly accepted Mr. R. D. Oldham's offer to prepare a fresh issue, accordant with our progressive survey of the Empire.
>
> Mr. Oldham had had a varied experience of survey work over widely separated tracts in India where he had opportunities of studying most of our representative formations in their peninsular and extra-peninsular development: while of his own motion he devoted his first period of well-earned leave to a comparative study of our Gondwána representative, in Australia. His close acquaintance with the literature, as evidenced in the careful *Bibliography of Indian Geology*, compiled by him in 1888, had already indeed predisposed me in favour of a possible ultimate placing of a second issue of the Manual in his hands; and in now authorising that issue I would fain hope that my choice may be justified.

I may add that a considerable part of the book has been largely re-written by Mr. Oldham; while the subjects of the Carboniferous and Triassic rocks of Extra-Peninsular India, the age and origin of the Himalayas, and the Geological history of the Indian Peninsula are discussed with a newness entirely attributable to his varied travel in India, and his grasp of the results worked out by his colleagues and himself. The issue of the book in the more convenient form of a single volume which, according to the whim of the reader, may be broken up into even more handy

sections through the page separation of the chapters; and a re-adjustment and increase of the plates and illustrations will be, it is hoped, an acceptable change on the aspect of the original edition.

A new fasciculus (Part I, Vol. II, Sec. IX) of the Palæontologia Indica, on the Echinoidea of Cutch, by Mr. J. W. Gregory of the Natural History Department, British Museum, was issued in July.

The gratifying intelligence was received in June from our friend Professor Ed. Suess of Vienna, that the large series of fossils collected last year during the Central Himalayan Expedition is now under active study and description. Dr. Diener himself is hard at work with the lower triassic Cephalopoda, towards the illustration of which we have already received ten of the fifteen plates which it is presumed will complete this section of the work. It is understood that all these Muschelkalk forms are new except two. Oberbergrath von Mojsisovics, who is investigating the upper trias forms, notes that the lower Himalayan trias contains several forms of the Siberian trias, and that Austrian types occur in the higher beds. Professor Uhlig and Dr. Francis Suess are engaged on the fossils of the Spiti beds, which will require from forty to fifty illustrative plates; while Dr. Bittner has undertaken the Rhœtic fossils.

The interest attached to this remarkable and richly representative collection of fossils may indeed be estimated from the consideration that our publication of the results is expected by the Austrian savants to bring about quite a change in the aspect of a good part of the Mezozoic marine faunæ The whole series, including the fossils previously sent to Vienna, which were originally collected by Stoliczka, Godwin-Austen, Theobald, Hughes, Griesbach, and Lydekker is so far-reaching in its bearings that it has been brought into comparative study with the fossils collected by Bogdanovitch and the Russian geologists during their sojourn in the Pamir and Kuenlun, which have been sent down to Vienna from the St. Petersburg Institute of Mines.

The Bhaganwala coal-field exploration was closed on the 6th July. It is gathered from Mr. LaTouche's abstract report on the field that:

"The evidence of the distribution of coal in this field is of two kinds, (*a*) that afforded by the natural outcrops, which surround the greater part of the area, and (*b*) that afforded by the drifts, which have been put in at various points along the outcrops.

(*a*) A study of the first shows that the distribution of coal is extremely irregular, and that the good coal of workable thickness which is exposed at certain points dies out, if traced along the outcrops, and becomes replaced by sandstones and shales.

(*b*) This evidence is borne out by that of the drifts, none of which, except those that were started in good coal at the outcrop, have proved the existence of a workable seam further in, or even an improvement in the outcrop indications.

"The conclusion to be drawn is that in making an estimate of the quantity of coal available, we are justified in taking into account only those areas in which the existence of good coal has been proved, and adding an amount, not actually proved, depending on the distance beyond those areas, to which the coal seam may be reasonably supposed to extend.

"The amounts thus calculated are—

From the areas actually proved, 88,480 tons.

From those in which the existence of good coal may be reasonably assumed, about 900,000 tons; or a total of, say, one million tons of coal.

"The conditions under which the coal is found are distinctly favourable for mining purposes, as the workings will have a good floor and roof of sandstone, and except where the mines are carried to a considerable depth, no great influx of water need be anticipated."

Field operations in Burma were closed early in May; and reports have been sent in to the Burma Government by Dr. Noetling for the Wuntho Division of the Katha District, and by Mr. Bose for the Tennassarim District.

The Director returned from touring in Burma on the 13th of May, whither he had gone on the 18th of April, closing the month with a short visit to the Warora Collieries in the Central Provinces. At Rangoon, he conferred with the Financial Commissioner on the examination of the reported gold finds in the Wuntho Division; and then proceeded to an inspection of the coal tract on the great Tenasserim river which was being explored by Mr. Bose, assisted by Mr. Datta. The auriferous tract in Wuntho, which may extend over a very large area, some 2,000 square miles, has only been touched as it were; the efforts of Dr. Noetling having been devoted to an examination of several spots indicated by applicants for prospecting or leasing blocks, adjacent to which block surveys were being made by the Survey of India party. The area so far appears to be one of extensive development of volcanic agglomerates and diorites, occasionally traversed by quartz veins some of which are auriferous; but a fair estimate of the possibilities of the region cannot be formed until a more extended geological examination is made, after the rains and their effects in such a wild jungly region have cleared off.

The coal exploration in Tenasserim is closed; and Mr. Bose's report confirms the previous estimate by Mr. Hughes, namely, that the presumable quantity of available coal under not difficult working is about a million tons; extended and deeper working might yield half as much again.

While prosecuting this exploration Mr. Bose was fortunate in obtaining a small collection of fossils from the strange cavernous limestones in the formation below the series in which the coal just mentioned occurs, which prove the long apprehended carboniferous age of this yet lower series; though the few carbonaceous traces occurring in this series are too poor to be considered of any commercial value. A description of these finds is furnished in the present number of the Records by Dr. Noetling, the Palæontologist.

Mr. Middlemiss has completed his survey of the Hazara District; and is now engaged on the preparation of a Memoir on its geology. Towards the end of this season a further find of what seemed to be a promising outcrop of coal was made near Juswal among the hills, four miles south-east of Abbottabad in the valley of the Dore river, though at a height of 2,500 feet above the level of the river, up the very steep slope of a rather inaccessible ridge. The coal is much like that in Hewson's locality, to the north-east of Abbottabad, *i. e.*, much crushed up and mashed by being cut through and through by shear planes; and being locally from 10 to 17 feet thick, it looked much more promising than that of Hewson's shaft. A very careful extraction of foot by foot of a large sample was sent down to Calcutta, but on assay (given in the list of assays appended further on), the percentage of ash in 9 feet, averaging 46·03, is altogether prohibitive. At the tenth foot, there is a decided improvement, with only 17·20 of ash and 65·80 of fixed carbon, but below this the average ash percentage is again as high as 31·95; so that the best we can say is that the better portion of the seam can only be useful for brick and lime burning.

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1893.

<table>
<tr><th>Substance.</th><th>For whom.</th><th colspan="4">Result.</th></tr>
<tr><td>1 specimen of coal.</td><td>Anara Valley Coal Syndicate Calcutta</td><td colspan="4">Proximate analysis, with calorific power and sulphur determination.</td></tr>
<tr><td rowspan="11">16 specimens of coal, from Begarmal near Juswal, Hazara.</td><td rowspan="11">C. S Middlemiss, Deputy Superintendent, Geological Survey of India.</td><td></td><td>1</td><td>2</td><td>3</td></tr>
<tr><td></td><td>"No. 1 from the top; first 4 feet."</td><td>"5 feet from the top."</td><td>"6 feet from the top."</td></tr>
<tr><td>Quantity received.</td><td>4 lbs.</td><td>3 lbs.</td><td>3 lbs.</td></tr>
<tr><td>Ash percentage.</td><td>53·04</td><td>58·70</td><td>37·12</td></tr>
<tr><td>Colour of ash</td><td>Reddish grey.</td><td>Light red.</td><td>Light red.</td></tr>
<tr><td></td><td>4</td><td>5</td><td>6</td></tr>
<tr><td></td><td>"7 feet from the top."</td><td>"8 feet from the top."</td><td>"9 feet from the top."</td></tr>
<tr><td>Quantity received.</td><td>4 lbs.</td><td>3½ lbs.</td><td>2 lbs.</td></tr>
<tr><td>Ash percentage.</td><td>54·52</td><td>37·60</td><td>35·20</td></tr>
<tr><td>Colour of ash</td><td>Light red.</td><td>Reddish grey.</td><td>Dark red.</td></tr>
<tr><td colspan="4">7
"10 feet from the top."
Quantity received . . . . 3 lbs.
Moisture . . . . 5·20
Volatile matter (exclusive of moisture) . . 11·80
Fixed carbon . . . . 65·80
Ash . . . . 17·20
100·00

Does not cake. Ash—light red.</td></tr>
</table>

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1893—continued.

Substance.	For whom.	Result.			
			8	9	10
			"11 feet from the top."	*"12 feet from the top."*	*"13 feet from the top."*
		Quantity received	*4 lbs.*	*3½ lbs.*	*3 lbs.*
		Ash percentage.	33·20	34·12	22·60
		Colour of ash	Light red.	Light red.	Red.
			11	12	13
			"14 feet from the top."	*"15 feet from the top."*	*"16 feet from the top."*
		Quantity received.	*4 lbs.*	*4 lbs.*	*3 lbs.*
		Ash percentage.	21·20	35·80	22·48
		Colour of ash	Red.	Reddish grey.	Red.
			14	15	16
			"17 feet from the top."	*"18 feet from the top. Bottom ft. 8 seam."*	*Selected specimen. Begarmal near Juswal.*
		Quantity received.	*3 lbs*	*4 lbs.*	*9½ lbs.*
		Ash percentage.	32·92	56·12	22·20
		Colour of ash	Dark red.	Light red.	Light red.
"One specimen of ore for determination" from Hazaribagh.	B. L. Tirzoni	Iron pyrites.			
One specimen of Coal from Pwela at Nan-Kon, Burma.	C. G. Bayne, Revenue Secretary to Chief Commissioner, Burma.	*Quantity received*			*7 lbs.*
		Moisture			17·42
		Volatile matter			38·66
		Fixed carbon			32·32
		Ash			11·60
					100·00
		Does not cake. Ash—buff			

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1893—continued.

Substance.	For whom.	Result.
11 specimens of coal.	R. A. Donnithorne, Secretary to the Commissioners for the Port of Calcutta.	Proximate analysis, with calorific power.
3 specimens of coal.	Finlay, Muir and Co., Calcutta.	Proximate analysis.
5 specimens of coal from the "Hosannah Seam, Pit I."	Finlay, Muir and Co., Calcutta.	Proximate analysis.
1 specimen sent as "Ruby Silver Ore."	C. M. P. Wright, Wuntho, Burma.	Micaceous iron ore.
Three specimens of iron ore, and one specimen of limestone from Burma.	P. N. Bose, Geological Survey of India.	Iron ore (limonite) from Maha Champa:— *Quantity received 4lbs.* Contains . . . . . 37·58 % Fe. Iron ore (limonite) from Therabwin:— *Quantity received 9lbs.* Contains . . . . . 50·49 % Fe. Iron ore (limonite) from above Banlaw, Tenasserim Valley:— *Quantity received 1 lb. 6oz.* Contains . . . . . 36·06 % Fe. Limestone from Therabwin:— *Quantity received 1 lb.* Insoluble in dilute hydrochloric acid . . . 13·40 Oxide of iron and alumina . . . . . ·61 Carbonate of lime . . . . . . 85·85 Carbonate of magnesia (by difference) . . ·14 100·00
One specimen of pyritous quartz, from Kabiotoung, about 3 miles west of Pinlon Village, north of Wuntho, Kawlin Subdivision, Burma.	Fritz Noetling, Geological Survey of India.	*Quantity received 5 lbs.* Contains no gold.
One specimen of galena and one of iron pyrites.	R. A. D. Sewell, Prospecting Officer, Rewah State.	Galena, with quartz from the "Workings at Orgari":— *Quantity received 22 lbs.* Yielded on assay—61·60 per cent. of *lead*, and 7 oz. 16 dwt. 19 grs. of *silver* to the ton of lead. *Quantity received 4 lbs.* Iron pyrites. Contains no gold.

List of assays and examinations made in the Laboratory, Geological Survey of India, during the months of May, June, and July 1893—concluded.

Substance.	For whom.	Result.
2 specimens of supposed Tremenheerite.	P. N. Bose, Geological Survey of India.	Carbonaceous shale from "Tagu"—Tenasserim :— *Quantity received 2 lbs.* Contains 87·12 % ash. Ash—Dark brick red. Carbonaceous shale from Woona, Tenasserim Valley, Mergui District :— *Quantity received 1 lb.* Contains 88·00 % ash. Ash—light buff.
1 specimen of coal from Nazira, Assam.	Kilburn and Co., 4, Fairlie Place, Calcutta.	Proximate analysis.
1 specimen of coal from Makum, Dibrugarh, Assam.	Kilburn and Co., 4, Fairlie Place, Calcutta.	Proximate analysis.
2 specimens coal .	R. A. Donnithorne, Secretary to the Commissioners for the port of Calcutta.	Proximate analysis with calorific power.
A rock specimen from top of Parasnath Hill, Hazaribagh.	W. Saise, Giridih.	Granitite or quartz diorite—quartz, plagioclase felspar, augite under process of uralitization, hornblende, garnet, with radiating fibrous reaction zones, and biotite. Structure granitic, in places granular.
2 specimens of coal from Darjeeling.	John King and Co., Limited, 30, Strand Road, Calcutta.	Proximate analysis, with calorific power and sulphur determination.
6 specimens of coal.	Finlay, Muir and Co., Calcutta.	Proximate analysis.
One specimen, of quartz with iron pyrites and visible gold.	Gillanders, Arbuthnot and Co., Calcutta.	Assayed for gold.

Notification by the Geological Survey of India during the months of May, June, and July 1893, published in the "Gazette of India," *Part II.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Geological Survey Department.	925, dated 20th June 1893.	F. Noetling, Palæontologist, Geological Survey.	Privilege	15th July 1893.	...	...

Annual increments to graded officers sanctioned by the Government of India during May, June, and July 1893.

Name of officer.	From	To	With effect from	No. and date of sanction.	REMARKS.
	R	R			
R. D. Oldham, Superintendent, Geological Survey.	900	950	1st May 1893.	Revenue and Agricultural Department No. $\frac{1249}{127}$, dated 25th May 1893.	
W. B. D. Edwards, Assistant Superintendent, Geological Survey.	380	410	1st July 1893.	Revenue and Agricultural Department No. $\frac{1719}{159}$, dated 18th July 1893.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. HUGHES . . .	On furlough . . .	
C. L. GRIESBACH . . .	Calcutta	Calcutta.
R. D. OLDHAM	On furlough.	
P. N. BOSE	Calcutta	Calcutta.
T. H. D. LATOUCHE . . .	Dalhousie	Dalhousie.
C. S. MIDDLEMISS . . .	Calcutta	Calcutta.
W. B. D. EDWARDS . . .	Quetta . . .	Quetta.
P. N. DATTA	Calcutta	Calcutta.
F. NOETLING	On leave	
HIRA LAL	Calcutta	Calcutta.
KISHEN SINGH	Mandra	Mandra.

DONATIONS TO THE MUSEUM.

FROM 1ST MAY TO 31ST JULY 1893.

Nine specimens of minerals from Eckak Village, Chota Nagpore.

PRESENTED BY M. ANDERSON, CALCUTTA.

One specimen of "Stone with the first glacial stride observed in the Carboniferous Boulder bed near Brauxton, New South Wales."

PRESENTED BY R. D. OLDHAM, GEOLOGICAL SURVEY OF INDIA.

One specimen of Elæolite-Syenite, from Junagadh, Kathiawar.

PRESENTED BY J. W. EVANS, D.SC., L.L.B., F.G.S., JUNAGADH.

Fifty specimens of rocks and minerals from the Madras Presidency.

PRESENTED BY F. G. BROOK-FOX, F.G.S., CHICACOLE, GANJAM DISTRICT.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1893.

Titles of Books. *Donors.*

BRONN'S Klassen und Ordnungen des Thier-Reichs. Band IV, lief. 28-30; and VI, Abth. IV, lief. 42-43. 8° Leipzig, 1893.

BROWN, *H. Y. L.*—Report on country in the neighbourhood of Lake Eyre, South Australia. Flsc. Pam. Adelaide, 1892.

THE AUTHOR.

FRITSCH, *Dr. Ant.*—Fauna der Gaskohle und der Kalksteine der Permformation Böhmens. Band III., heft 2. 4° Prag, 1893.

KLEIN, *Dr. H. J.*—Jahrbuch der Astronomie und Geophysik. III. Jahrgang, 1892. 8° Leipzig, 1893.

MARCOU, *Jules.*—A little more light on the United States Geological Survey. 8° Pam. Cambridge, Mass, 1892.

THE AUTHOR.

MARCOU, *Jules.*—On the classification of the Dyas, Trias, and Jura in North-West Texas. 8° Pam. Cambridge, Mass, 1892.

THE AUTHOR.

MARCOU, *Jules.*—Second supplement to "Mapoteca Geologica Americana," 1752-1881. 8° Pam. Cambridge, Mass, 1893.

THE AUTHOR.

NICHOLLS, *H. A. Alford.*—A Text-Book of Tropical Agriculture, with illustrations. 8° London, 1892.

NOETLING, *Dr. Fritz.*—Notes on the Mineral Resources of Upper Burma. Flsc. Pam. Rangoon, 1893. BURMA GOVERNMENT.

Palæontologie Française, 1re série, Animaux Invertebres. Terrains Tertiaires, Éocéne Échinides. Liv. 29. 8° Paris, 1893.

Titles of Books. *Donors.*

PENCK, *Professor Dr. A.*—The construction of a map of the world on a scale of 1 : 1,000,000 (from the Geographical Journal for March 1893). 8° Pam. London, 1893. THE AUTHOR.

TROSCHEL, *Dr. F. H.*—Das Gebiss der Schnecken zur Begrundüng Einer Naturlichen Classification. Band II, lief. 8. 4° Berlin, 1893.

WATT, *Dr. George.*—Dictionary of the Economic Products of India, Vol. VI, part 2. 8° Calcutta, 1893. GOVERNMENT OF INDIA.

PERIODICALS, SERIALS, ETC.

American Journal of Science. Vol. XLV, Nos. 268-270. 8° New Haven, 1893.

American Naturalist. Vol. XXVII, Nos. 315-317. 8° Philadelphia, 1893.

Annalen der Physik und Chemie. Neue Folge, Band XLVIII, heft 3-4, and XLIX, heft 1-2. 8° Leipzig, 1893.

Annals and Magazine of Natural History. Vol. XI, Nos. 64-66. 8° London, 1893.

Athenæum. Nos. 3412-3424. 4° London, 1893.

Beiblätter zu den Annalen der Physik und Chemie. Band XVII, Nos. 3-4. 8° Leipzig, 1893

Chemical News. Vol. LXVII, Nos. 1738-1750. 4° London, 1893.

Colliery Guardian. Vol. LXV, Nos. 1681-1693. Fol. London, 1893.

Geological Magazine. New series, Decade III, Vol. X, Nos. 4-6. 8° London, 1893.

Indian Engineering. Vol. XII, No. 22, and XIII, Nos. 13-25. Flsc. Calcutta, 1893. PAT. DOYLE.

Iron. Vol. XLI, Nos. 1053-1065. Fol. London, 1893.

London, Edinburgh, and Dublin Philosophical Magazine, and Journal of Science. 5th series, Vol. XXXIII, No. 200 to XXXIV, No. 211; and XXXV, Nos. 215-217. 8° London, 1892-1893.

Mining Journal. Vol. LXIII, Nos. 3003-3015. Fol. London, 1893.

Natural Science. Vol. II, No. 12. 8° London and New York, 1893.

Nature. Vol. XLVII, No. 1220 to XLVIII, No. 1232. 4° London, 1893.

Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Band I, heft. 2-3. 8° Stuttgart, 1893.

Oil and Colourman's Journal. Vol. XIV, Nos. 152-154. 4° London, 1893.

Palæontographica, Band XL, lief. 1-2. 4° Stuttgart, 1893.

Petermann's Geographischer Mittheilungen. Band XXXIX, Nos. 4-5, and XL, No. 3. 4° Gotha, 1893. THE EDITOR.

Scientific American. Vol. LXVIII, Nos. 9-21. Fol. New York, 1893.

Scientific American. Supplement. Vol. XXXV, Nos. 896-908. Fol. New York, 1893.

The Indian Engineer. Vol. XVI, Nos. 312-324. Fol. Calcutta, 1893. J. MACINTYRE.

The "Pioneer." New series, 1st Edition, Vol. XCIV, Nos. 10002-10077. Fol. Allahabad, 1893. SUPDT. OF STATIONERY.

Zeitschrift für Krystallographie und Mineralogie. By P. Groth. Band XXI, heft. 3-4. 8° Leipzig, 1893.

GOVERNMENT SELECTIONS, REPORTS, ETC.

Titles of Books, *Donors.*

BENGAL.—Notes on the District of Gaya, by G. A. Grierson. 8° Calcutta, 1893.
REV. AND AGRIC. DEPARTMENT.

BOMBAY.—Selections from the Records of the Bombay Government. New Series, Nos. 263, 265 and 266. Flsc. Bombay. 1892-1893.
BOMBAY GOVERNMENT.

INDIA.—Census of India, 1891. Vol. XI, Part I, and XII, Part II. The Central Provinces and Feudatories. Flsc. Calcutta, 1893.
REV. AND AGRIC. DEPARTMENT.

„ General Report on the Operations of the Survey of India Department for 1891-92. Flsc. Calcutta, 1893. SURVEY OF INDIA DEPARTMENT.

„ List of Officers in the Survey and other Departments subordinate to the Government of India in the Revenue and Agricultural Department, corrected to January 1893. 8° Calcutta, 1893.
REV. AND AGRIC. DEPARTMENT.

„ Meteorological Observations recorded at seven stations in India, in the year 1892, corrected and reduced. 4° Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVT. OF INDIA.

„ Monthly Weather Review, November 1892 to January 1893. 4° Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVT. OF INDIA.

„ Register of Original Observations, reduced and corrected, November 1892 to January 1893. 4° Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVT. OF INDIA.

„ Quarterly Indian Army List. New series, No, 15. 8° Calcutta, 1893.
GOVERNMENT OF INDIA.

PUNJAB.—Gazetteer of the Hissar District, 1892. 8° Lahore 1893.
PUNJAB GOVERNMENT.

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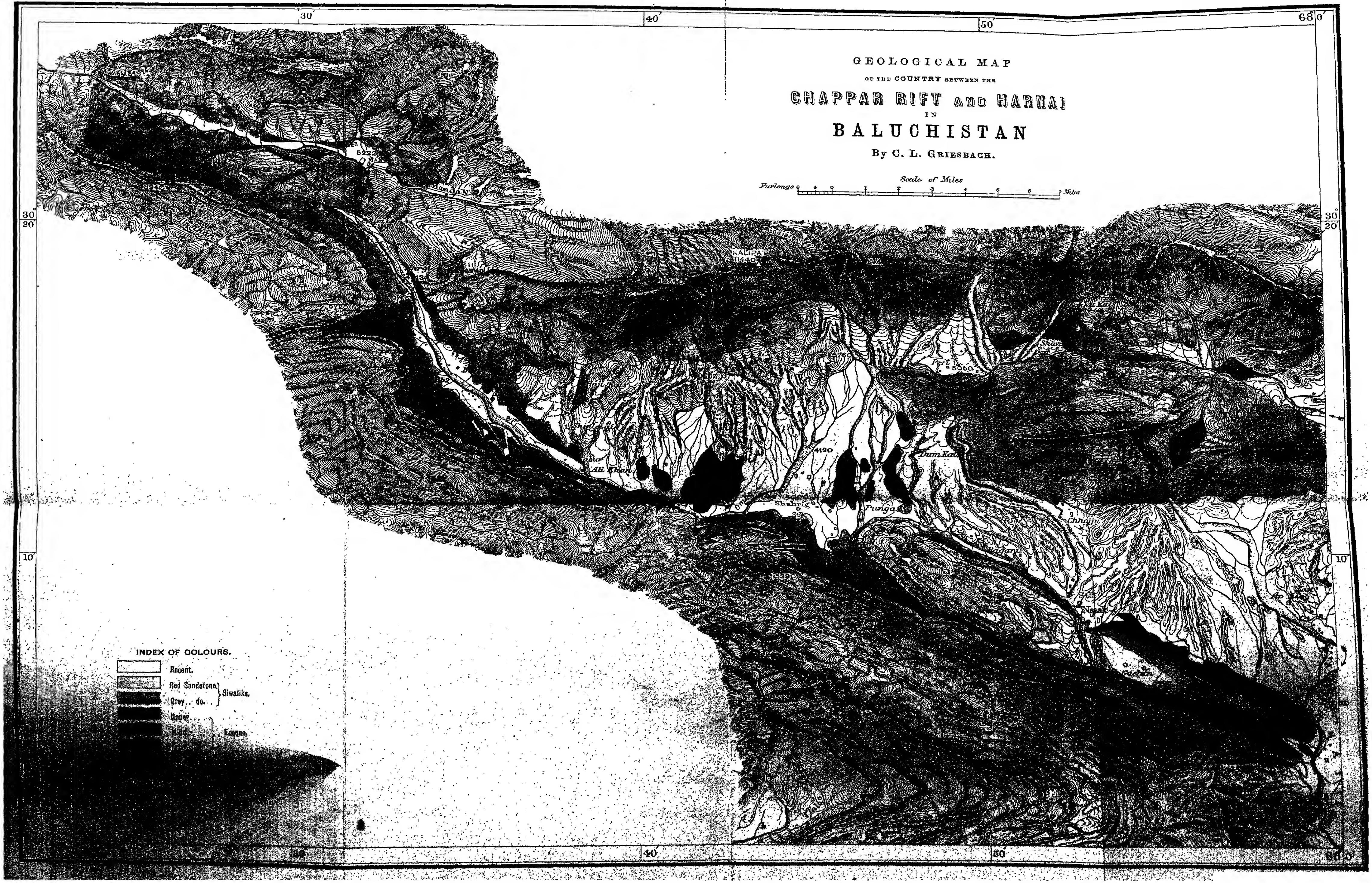

GEOLOGICAL MAP
OF THE COUNTRY BETWEEN THE
CHAPPAR RIFT AND HARNAI
IN
BALUCHISTAN
By C. L. GRIESBACH.
Scale of Miles
Furlongs
Miles
KALIPAT
4120
Dam Kat
Punga
Shahrig
INDEX OF COLOURS.
Recent.
Red Sandstone
Grey do.
Siwaliks.
Eocene.

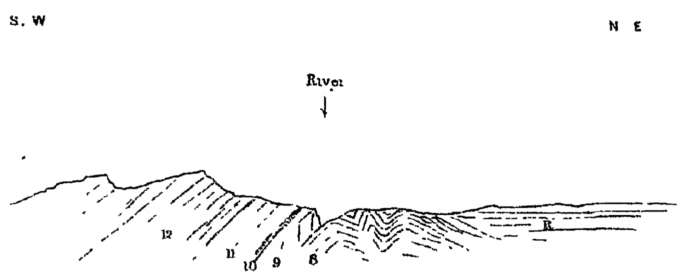


FIG. 1. SECTION BETWEEN ÁLI KHÁN AND OMBO EAST OF SPAR BÁZ

R. . Recent deposits
12. . . . Red Sandstones }
11. . . . Grey do } Lower Siwaliks
10. . . Chert Breccia }
9 }
8 } Upper Nummulitics } Upper }
3 . . . Coal-Seams }
1. . . . Green Shales & Sandstones } Middle } Eocene
B . . . Lower Nummulitic Limestone } Lower }
A . . . . . Belemnite beds } Cretaceous

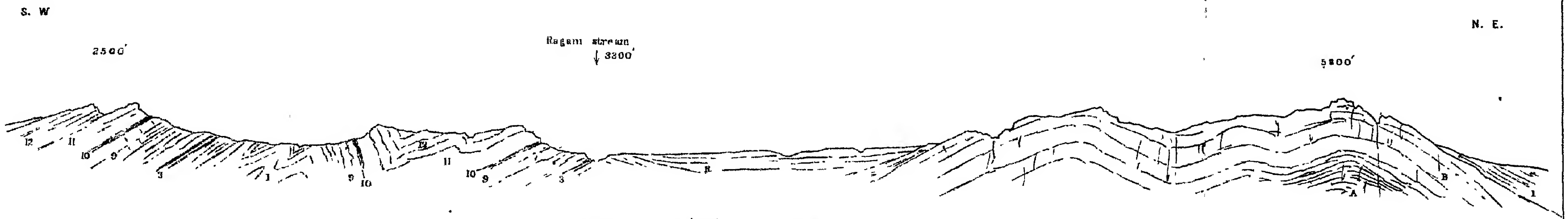


FIG. 2. SECTION BETWEEN THE SHÁHRÁG COAL-SEAMS AND THE WANGI ANTICLINAL.

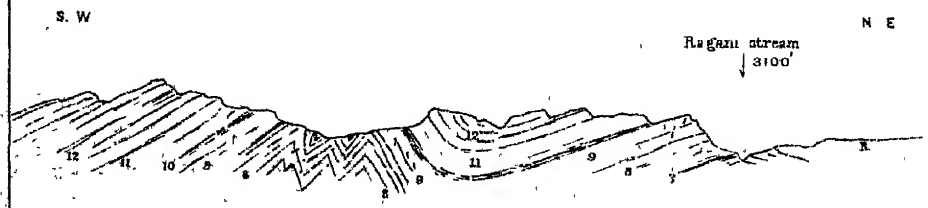


FIG. 3 SECTION WEST OF NASAK.

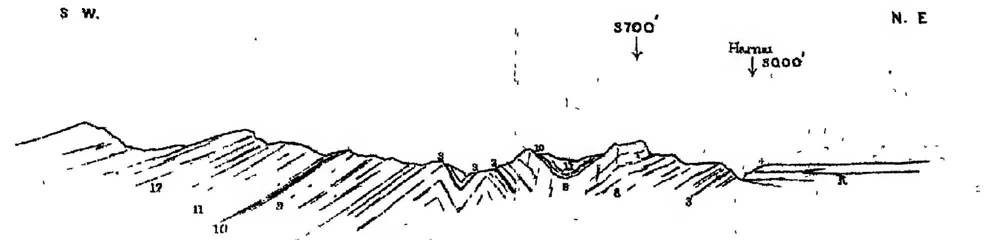


FIG 4. SECTION BETWEEN HARNAI AND THE HILLS S. W. OF IT.

RECORDS, VOL. XXVI PT. 4 PL. 2.

SECTION EXPOSED THREE MILES S.E. OF SHÁHRÁG.
LOOKING TOWARDS EAST.

GEOL. SURV. OFFICE IMP.

C.L. GRIESBACH

GEOLOGICAL SURVEY OF INDIA.

C.L. GRIESBACH DEL.

PROFILE OF THE HARNAI SYNCLINAL FROM THE PEAK (3700), 1½ MILES WEST OF HARNAI STATION, LOOKING S.E.

GEOL. SURV. OFFICE IMP.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1893. [November.

On the Geology *of the country between the* Chappar Rift *and* Harnai *in* Baluchistán, *by* C. L. GRIESBACH, C.I.E., *Superintendent of the Geological Survey of India.* With map and three plates.

I.—PRELIMINARY OBSERVATIONS.

The area described in these pages was geologically examined by me during the winter months of 1892-93 and comprises within it all the collieries opened out by the North-Western Railway between Khóst and Harnai.

Previous observers; W. T. Blanford.

The ground has been visited and reported on several times; the first geological description is contained in Dr. W. T. Blanford's Memoir "*Geological notes on the hills in the neighbourhood of the Sind and Punjab frontier between Quetta and Dera Ghazi Khán*"; chapter VI of this memoir notices some of the geological features of the country between Quetta and Sibi, and the author describes in some detail a section near Sháhrág.

In that Memoir the author discusses at some length my description of the geology of the Bolán and the Quetta area contained in Memoirs, Vol. XVIII; with regard to some points of it he comes to conclusions differing from mine, but as these do not affect the geology of the country here described, I have determined to postpone my reply to Dr. Blanford's criticism until I have not only re-visited some of my old sections, but also until I can give a more complete outline [of the geology of Baluchistán, and for the same reason I abstain from discussing points in the geology of the ground lying beyond the limits of the map accompanying this paper. For the present it will suffice to mention one single point of this discussion which materially affects the geology of the Khóst-Harnai sections. At page 11 of his Memoir Blanford says "that his lowest stage of the eocene system, in the Bolán pass and near Quetta, the *Alveolina* limestone, cannot be accepted as a definite subdivision"—and after stating that *Alveolinæ* occur also in higher horizons in the eocene, he mentions on page 15,—"there is no distinct band of limestone, whether characterised by the abundance of *Alveolina* or not, of sufficient importance to be distinguished as a primary subdivision or stage, either in the Bolán pass or near Quetta, at the base of the eocene system." I have since been in communication with the author;

Dr. Blanford still believes that a distinct limestone stage at the base of the eocene division cannot be otherwise than a local development, the limestone passing into shales and sandstones, both in Sind and Baluchistán. This may be the case but it is remarkable that up till now I have found that the lithological character of the tertiary sequence remains very constant, excepting near the centres of the then volcanic activity along the Kóják-Zhób line of country. At all events in the Quetta sections and the country here described the lower eocene is represented by far the most conspicuous formation, and perhaps,—excepting the Siwaliks,—by the greatest thickness of beds found to belong to any one of the rock-divisions of Baluchistán. Even palæontologically it is distinguished; whilst in the lower nummulitic limestone practically nothing but foraminiferæ, chiefly *nummulites*, in very large number have been found, the middle eocene (green shales, etc.) have so far yielded very few *nummulites*; but on the other hand numerous eocene *gasteropods, bivalves, echinoderms* and in some places even fresh-water mollusks. I think it is highly probable that the green shales, etc., of the middle eocene are a local development as seen near Khóst and Sháhrág and that elsewhere the fauna assumes a more pelagic character. Dr. Blanford himself has noticed the great development of the limestone which forms the base of the eocene, and I may here quote his notice of the rock-series near Harnai which is given on page 49 of his Memoir, namely:—

a. Olive shales and sandstones.
b. Nummulitic limestone.
c. Olive shales and sandstones.
d. Nummulitic limestone.

He says:—"Throughout the Harnai route below Kach the lower nummulitic limestone (*d*) forms immense hills, including the Pil and Chappar ridges, the upper part at least of the huge mountain mass north of Sháhrág and Harnai, and a number of hog-backed elongate hills of smaller elevation." This is essentially the position I take, excepting that I believe that this lower nummulitic limestone forms a constant horizon over a considerable area, and that it extends both into Khorassan and over the larger part of South-Western Afghanistán, and in fact is part of the great Mediterranean development of the eocene,—whilst Blanford considers it a local facies only.

E. I. Jones. Dr. W. King.

The first, rather more detailed examination of the area about Khóst was undertaken by the late Mr. Jones of the Geological Survey, who has left a manuscript report behind, which I have used in this paper, quoting him when doing so. Dr. W. King has given some extracts of this report in the Records, Vol. XXII, p. 149, and these consist chiefly of the economic side of the coal-fields near Khóst.

R. D. Oldham.

In 1889 Mr. Oldham was detailed for work in Baluchistán and the outcome were two papers which appeared in the Records of the Survey, namely:—

(1) *Report on the Geology and Economic Resources of the country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and of the country between it and Khattan*, Records, XXIII, p. 93; and

(2) *Report on the Geology of Thal Chotiáli and part of the Mari country*, Records, XXV, p. 18.

The substance of these papers is also contained on pages 289 to 293 of the second dition of the Manual of the Geology of India brought out by Mr. Oldham this year.

Generally agreeing with Oldham's views, I must differ from him in two particulars. In the first place I doubt the utility of adopting local names for subdivisions, the homotaxial positions of which are known. I have adopted the terms, *lower, middle* and *upper* nummulitic in place of his Dunghán, Ghâzij and Spintangi "groups."

The second point on which I differ from Oldham is of more importance.

This author described the thick-bedded limestone with *nummulites,* which I believe to form the base of the eocene division, as underlying the Ghâzij shales and to be nummulitic, but later he included this subdivision with the cretaceous system, which view he takes in the new edition of the "Manual."

In this, our interpretations completely differ. It has frequently been pointed out, and it is the opinion of most modern continental geologists, that the base of the tertiary system should be placed much lower down than it is at present, and that certain upper cretaceous beds, as for instance the upper hippuritic limestone of the Mediterranean, be included in the tertiary system. At all events until more is known of the organic life of the rather barren formations of the upper cretaceous, it seems a dangerous move to change from the old order, if for no other reason than that of convenience. And for this purpose it is perhaps best to accept it as a general rule that all beds with true *nummulites* be included in the tertiary system, making the beds below cretaceous. This I believe is now the view of most authors on the subject, and most continental geologists therefore separate a well-defined upper hippuritic horizon in Greece, Egypt, etc., with *nummulites,* from the lower *rudiste* limestone, which is cretaceous. Mr. Oldham, on the other hand, has done the reverse; he has extended the range of the cretaceous of Baluchistán into the confines of the lower eocene. In his second paper above quoted, he simply mentions of the "Dunghán group,"—my lower nummulitic limestone,—that its fauna is anomalous, and although in the absence of sections and detailed statements it is difficult to form an opinion whether this anomaly is confined to one particular point of observation or is shown elsewhere, it appears that he found *crioceras, baculites* and *ammonites* with an abundance of *nummulites.*

In the "Manual," however, this formation is boldly spoken of as cretaceous. and thus one of the most thickly developed and conspicuous formations of Baluchistán is removed from the tertiary system.

Without going into the discussion of the fossils closer, I may at once state that however interesting a find of *belemnites* and *ammonites* would be in *tertiary* beds of Baluchistán, it could not quite be looked upon as an anomaly.

In the eocene of Europe occur several genera of belemnites (in Zittel's sense), and some genera of *ammonites* have been described from the eocene of California. On the other hand, the upper hippuritic beds of the Mediterranean hitherto generally classed with the lower limestone horizons, as cretaceous, contain *nummulites* and are now included in the tertiaries. If, therefore, Mr. Oldham's observations were substantiated, the Dunghán limestone ought rather to become lower eocene, and this only in deference to the general usage of relegating to the eocene all beds with an abundance of true nummulites. And this would also be more in accord with stratigraphical facts, which point to a division of the tertiary system from the cretaceous immediately after the great post-cenomanian "transgression."

But fortunately I have had an opportunity of viewing Mr. Oldham's "anomalous" fauna since my last return to Calcutta, and in this I was advised by Dr. Noetling. It seems that all the cephalopods are true cretaceous forms, some of them in very fine preservation; they point to a lower rather than upper cretaceous age of the beds. There were *no nummulites* in the collection from these fossil-bearing beds, but well-preserved *orbitolites*, which occur in the cretaceous as well as tertiary systems. It seems, therefore, most probable to me, bearing in mind the fact that so far nothing but true tertiary forms with *nummulites* have been found in other localities in the "Dunghán limestone," that the observation referred to is not complete. I hope to have an opportunity this year of further studying this special locality.

Hill-ranges.

Geographically the area belongs to the system of ranges and valleys which form the eastern part of Baluchistán. These ranges are disposed in a series of parallel lines east of Quetta, where they continue in a gentle curve towards east, gradually turning north-east and northwards until they merge into the system of the Sulaiman range which forms the natural and mountainous barrier between the Punjáb and Baluchistán. The most striking feature of these parallel ranges is the great bend near which the cantonment of Quetta is situated; the re-entering angle formed by them is occupied by a very complicated series of parallel ridges composed of rocks of Siwalik age, which have grouped themselves round the great massif of the Zarghún. Between these ranges which are chiefly made up of Siwalik strata, and the next adjoining chain of hills, a depression or trough extends all round the Zarghún massif with its skirt of parallel ridges,—which trough forms part of a series of wide valleys. I shall have occasion to refer to this feature in this paper and propose to call this depression made up of a series of valleys,—the "trough." The area immediately under discussion in this paper may be defined as lying between the system of Siwalik ridges to the south and south-west, and the precipitous limestone range of the Khaliphát, near the western termination of which the Chappar Rift is situated.

South of Mangi, a station on the North-Western Railway, an absolutely bare limestone range closes the valley on its right side: it is one of the most perfect examples of a simple anticlinal. About four miles west of Mangi this fold is seen to gradually dip conformably below younger beds which surround the hog-backed range on three sides near its western termination. From that point the range may be followed eastwards; it forms at first a slight bend to south-east and then trends away due eastwards,—always preserving its character of an anticlinal fold. About six miles north-east of Sháhrág station another range of similar composition and structure commences and follows an easterly direction.

These ranges form the northern margin of the depression or trough to which I have been alluding.

The southern ranges are of simpler structure; a scarp, formed by a sequence of tertiary beds, faces northwards and is skirted along its face by several secondary flexures made up of the same beds,—the whole forming a ridge or ridges about 2,000 feet above the level of the "trough."

The northern margin of the latter, formed by the limestone anticlinals described, rises to much greater altitudes; varying in height a good deal, there are elevations of 10,000 to 12,000 feet to be found in it, and it generally presents a very imposing aspect, particularly in winter when it is covered by masses of snow.

Rivers.

The drainage of this area is roughly speaking directed from north to south; the trough or depression aforementioned does not form one valley but is divided into several catchment areas by low passes, mere swells of the ground, whilst the drainage escapes through the ranges by a series of narrow defiles,—true transverse valleys of erosion.

The first stream which we must notice, and at the same time one of the best known amongst them, is the Khóst river. It flows along the valley in which Mud-gorge and Mangi are situated, receives some slight additions before reaching Mangi and then escapes through the Chappar range by way of a narrow defile, eroded out of the hard limestone anticlinal. After traversing this range almost at right angles to its strike the river flows in the natural trough of Dirgi and Khóst running in a more or less south-easterly direction to a point about 2 miles south-west of the village of Ombo, whence it flows through a succession of narrow defiles eroded out of the parallel ranges of tertiary strata which form the southern margin of the "trough." On its way to this defile the Khóst river receives a number of small tributaries on its left side, which drain and erode both the southern slope of the Khaliphát range and the great fans which stretch from the latter southwards. East of this system of drainage is the rising ground of Sháhrág with the great buttress formed by a hill south of it, which together make up the watershed between the Khóst river and the Punga stream, which also works its way through narrow defiles and escapes south. East of the Punga stream, another rise in the ground forms a watershed between the latter and the Nasak drainage. The latter has its source amongst the high hills of the Khaliphát range near Ziárat; after flowing in deep and narrow ravines in this range it breaks through the Wangi range in two defiles, mere slits in the hills, and after traversing the fans in numerous deep channels the river collects near Nasak and has cut its way through the ranges south of it forming a succession of narrow tangis or defiles.

The Harnai drainage is similarly formed; separated from the more western Nasak stream by high ground, the Harnai river itself rises in the eastern continuation of the Khaliphát range, flows through a narrow valley scooped out of the southern range (north of Harnai), called the Wam Tangi, and then flows southwards as the rivers further westwards are doing.

This drainage brings us face to face with one of the great and interesting problems of frontier geology,—namely, the transverse valleys. I cannot here discuss the many theories which have been advanced to account for these defiles; the literature concerning these and similar valleys is immense and the views often very divergent. The common belief no doubt is that these narrow defiles have been caused by some great cataclysm, which had torn asunder the hill ranges and so opened the road for the waters to escape. I need hardly say that there is no evidence to support this view, and though it is quite possible that one explanation could never be applicable to all cases, it may be assumed beyond doubt that the defiles in Baluchistán are in the vast majority of cases the result of gradual erosion by the existing rivers, that is to say that the erosion took place simultaneously with the folding and consequent elevation of the strata and that the softer ones of the latter have suffered more by this gradual erosion than the harder rocks, which would account for the gradual widening into broad valleys of those parts

which are composed of softer beds, mostly shales and clays. The possibility is not excluded,—it is even highly probable,—that as erosion went on simultaneously with the folding that occasionally the drainage became dammed up and thus lakes were formed, only to disappear again as erosion cut down deeper into the confining rim.

Structure.

The ground described here has in common with the rest of Baluchistán undergone great disturbance in the manner of folding and crushing of its strata. One remarkable feature which must be noticed is the frequent coincidence of mountain ranges with natural anticlinals on the one hand and the marked regularity of what Prof. Suess called a scaly structure in other cases, which latter produces the recurrence of parallel hill-ranges, which present a scarp on one and a dip-slope on the opposite side. Whilst the anticlinal ranges are commonest seen in the lower limestones (upper cretaceous and nummulitic), the latter structure is repeated with strange regularity in the areas occupied by beds of Siwalik age. Partly the structure of these latter rocks is owing to an alternation of harder and softer beds, which, yielding to sub-aerial denudation in a different manner, assume the appearance of a "scaly" structure where the beds are inclined. But I am convinced by the evidence of what I saw in the field that this alone will not account for the apparent enormous sequence of such beds and that the explanation of it is frequently a combination of unequal denudation with a series of parallel faults which have repeated sequences of beds, thus producing the semblance of what would otherwise constitute an enormous thickness of beds forming a natural sequence.

Besides these two great features of mountain formation which are even noticeable during a flying visit to Baluchistán, we have often considerable areas occupied by softer strata (sandstones and shales of middle eocene) which are tremendously crushed and folded between the harder series of rocks within which they occur. Such for instance is the case in the " trough " aforementioned and along which the line of railway to Quetta has been laid. This area shows the beds, where they are exposed below the recent alluvium and fans, crushed and folded in such a manner that a correct estimate of their thickness or nature would be quite out of the question. Only where such beds have been protected by a great weight of overlying strata is their section at all clear.

The anticlinal ranges are running more or less from east to west within the area under description, and they may be said to be echelonned and advancing southwards from the eastern flank. The Khaliphát range (of which the Chappar is the westernmost extension) is a fine example of such an anticlinal. The hill-ranges which form the southern margin of the "trough" show the scaly structure, whilst the "trough" itself is occupied by the crushed and much-disturbed beds of the middle eocene.

One more structural feature remains to be noticed, and that is the large extent and perfect development of fan deposits which slope down gently and evenly from the high (anticlinal) ranges af the Khaliphát and Wám hills, and which to a large extent fill the "trough," at the same time obscuring the underlying beds.

Disturbing causes.

It would be impossible to enter here into a discussion of the causes which have led to the wrinkling and folding of the strata of Baluchistán. Scarcely enough material for such discussion has been collected yet, and all we can say at present is that the disturbance in this

country belongs to the extended system of mountain folding which has been termed the Iranian system of folds; this system of mountain formation extends far into Persia and there forms wide zones of parallel folds, which are closely connected with the loops and zones of the hill-ranges of Baluchistán, and through the latter with the ranges of the Mari country, and finally merge into the north-south chain of the Sulaimáns.

The period when the greatest disturbance—contraction into folds—took place, probably belongs to late miocene times, though many changes in the distribution of land and sea had already taken place during the latter end of the eocene age.

Whether there was a period when this tendency to contract the sediments into folds lessened in intensity, is difficult to say, but certain it is that the same forces were still at work at a much later period and are probably being actively continued now. That this is the case is shown plainly by the tremendous disturbance which the younger tertiaries (Siwaliks) down to the recent (Indus) gravels have suffered, which are laid into folds and frequently raised up vertically.

Frequent earthquakes and even dislocations (see Records, Vol. XXVI, p. 57) which are a common experience in Baluchistán and indeed all along our frontier, are no doubt closely connected with this folding process.

Dislocations.

That such crushing and folding could not pass off without leading to dislocations and faults must be evident. Within the area described here larger dislocations are absent, though smaller faults and slips are so common, particularly along the scarp facing north of the southern margin of the "trough," that it has not only rendered a really detailed and correct survey of the geological features difficult if not impossible, but has proved a most unpleasant feature in the coal-mining operations which the North-Western Railway carries on along this scarp. Several of the more evident of these faults I have entered on the map, more to show the system of these slips diagrammatically than intending to place on record any individual fault.

Joints.

In like manner large cracks, or rather joints, run through the harder rocks (mostly limestones) of the anticlinal ranges which bound the area northwards. They may be seen on the absolutely bare hill-sides, mostly dip-slopes, as for instance on each side of the Chappar; they run in long straight lines, intersecting each other at all angles and are frequently widened out by the eroding agency of water which percolates into these joints, and converts some of them into small defiles.

"Rifts."

The "rifts" have been eroded out mainly and almost solely by the agency of flowing water, and they represent true cases of transverse valleys as already stated; but at the same time it could not be denied that the joints and cracks spoken of, which in several instances may be observed in all the stages of mere cracks to miniature defiles, must have frequently been the first cause of the formation of such defiles, although as the erosion progressed the original direction given perhaps by a small fissure, or joint, would be altered until finally it would be impossible to recognize in the tortuous course of the defile any original main joint plane.

II.—FORMATIONS.

Passing from south to north across the ground here described an entirely normal

sequence of rocks is met with from the younger tertiaries (Siwaliks) to beds which may belong to the cretaceous system.

In descending order I observed :—

		Rocks.	Thickness in feet.
PLIOCENE	Upper	Grey sandstone	3,000?
	Lower	Red and purple sandstones with shaly beds	2,000?
		Grey sandstone, near base calcareous grits and conglomerate	700?
NUMMULITIC	Upper	Nummulitic limestone, concretionary. Sandstone, near base conglomerate	500
	Middle	Bright coloured sandstones and shales, fossils. Gypsiferous shales, sandstone and olive-coloured beds with coal-seams	650
		Greenish sandstone and shales	800
	Lower	Grey limestone with nummulites, etc., about	200,5
Upper cretaceous?		Red and purple shales, sandstone, etc.	300

Cretaceous beds.

The transverse valleys of the Chappar Rift and of the Wám Tangi (north of Harnai) are the only localities where rocks older than the nummulitic formation have been met with in this area. The outcrop seen in the Wám Tangi is of small extent and not very characteristic. The Tangi traverses a single anticlinal of hard dark-grey limestone with nummulites, which represents the lower eocene subdivision; near the centre of the anticlinal light green, marly limestone with shaly partings appears in which I have found no fossils. But there is no difficulty in correlating this horizon with similar shales which occupy the same stratigraphical position in the hills further eastward and in which Mr. Oldham has found *belemnites*, and which horizon may be looked upon as forming approximately the upper limit of the cretaceous system.

Better developed are similar shales with marly and sandstone beds, which occur in the Chappar Rift in a similar stratigraphical position below the lower nummulitic limestone. There they consist of green shales with sandstone layers and deep purple to reddish shales which contain strings of gypsum. I have not found any fossils in this subdivision, but *belemnites* have been obtained from these beds by Mr. LaTouche.

Lower nummulitic limestone.

The following subdivision forms by far the most conspicuous series of strata in Baluchistán. Range on range running in long parallel lines, consist almost entirely of the grey limestone beds of this series. The long line of hills, beginning some few miles west of the Chappar Rift and continuing eastwards as the Khaliphát range, is formed of a simple anticlinal of lower nummulitic strata. North of the Harnai hills extends another anticlinal range made up of the same limestone. The total thickness of this series of beds can hardly be less than about 3,000 feet; at the Takatu hill the same series may possibly reach a thickness of 4,000 to 4,500 feet, and this I believe is the maximum thickness of the formation.

Lithologically there does not seem much difference between this subdivision of the nummulitics and the massive limestone of the cretaceous system (the hippur-

itic limestone) which I have met with elsewhere in Baluchistán. It is a hard dark grey, occasionally almost white limestone consisting mostly of thick beds. The surface of the dip-slopes, whic h usually form the bare hill-sides are honeycombed and deeply cut into by cracks and fissures, which render the climbing of even very steep ascents a peculiarly easy task.

Within this thickness of dense grey limestone are several horizons at regular intervals, which at least in the Chappar Rift section seem to increase in frequency and thickness. These horizons consist of a concretionary limestone, which from a distance and on weathered surfaces strongly resembles a conglomerate. A similar facies of rock occurs in the upper nummulitic limestone (Oldham's Spintangi's) and I could discover no very marked difference between the two. Similar rock, well known to German geologists as "Knollenkalk," I have seen in other formations and localities. The softer portions which fill the space between the limestone concretions disintegrate on the weathering surfaces and thus leave the individual lumps of limestone isolated, giving the whole rock a conglomeratic appearance. Nodules and concretions of chert are not uncommon in this horizon.

The only fossils which I have found in this limestone are casts of gasteropods and bivalves with numerous *nummulites* and *alveolinæ*.

During my first visit to Baluchistán in 1880 I distinguished this horizon as the "*alveolina* limestone." Mr. Oldham has described the same subdivision as the Dunghán limestone; but there seems to be some uncertainty whether beds in which Mr. Townsend has found true lower or middle cretaceous *ammonites* and which Mr. Oldham doubtfully included in his Dunghán group, as well as other beds from which Mr. Oldham collected *ammonites*, *belemnites*, *echinoderms* and *bivalves* of true lower or middle cretaceous type, together with *foraminiferæ*, not *nummulites*, and which Oldham includes with the Dunghán limestone, should be really correlated with the limestone of the Chappar, the Khaliphát and the upper limestones of the Wám Tangi, while all of them have up to the present not yielded anything else but true eocene types of fossils.

The occurrence of *nummulites* together with what are usually considered upper cretaceous forms, as for instance *rudistes*, is well known; and in Egypt, Asia Minor and Greece *nummulites* are numerous and common in the Upper Hippuritic limestone, hitherto considered upper cretaceous: indeed there are not only palaeontological but stratigraphical reasons why the tertiary system should have been fixed at the base of the cenomanian rather than is done at present. But this difficulty does not affect the present question; neither does the established fact that both *belemnites* and *ammonites* do occur in the tertiary system, several forms of the latter being unquestionably represented in the tertiaries of California.

The difficulty seems to me to lie in the circumstance that (1) not sufficient proof has been given that the lower nummulitic limestone of the Takatu, the Chappar and Khaliphát ranges are really identical with the *ammonite*-bearing limestone, (2) the supposed *nummulites* which have been collected with these lower or middle cretaceous forms are not *nummulites* but species of *orbitolites*. Probably an opportunity will occur of studying this locality once more during the coming season, and I will defer further remarks until this has been done.

Middle eocene.

From an economic point of view the most important formation represented in Baluchistán is the considerable thickness of shales and sandstones which forms the middle portion of the eocene,

and rests conformably on the lower nummulitic limestone in all the sections examined. Whilst the latter is obviously a pelagic formation, the character of the beds which overlie it, points to the probability that it was formed either in a lagoon or close to, and in between shallow portions of a coastline, some of its deposits possibly even within the delta of a river.

Not only the lithological character of the beds but also their fossil contents point to such conclusions. Sandstones, generally of a greenish-brown colour, occur locally near the middle portion of the series, which are clearly of fresh-water origin as the numerous specimens of *Unio* show. The rest of the strata consist mostly of greenish-grey sandstones (often extremely like the lower Siwaliks in appearance), shales and clays and subordinate layers of impure limestone with coarse grits higher up. Gypsum in leaflets, nests and veins is common throughout the formation, but especially frequent in the lower half of the subdivision.

The usual phenomena may be observed which are connected with the occurrence of gypsum; the expansion of it (of the anhydrite associated with it) and subsequent dissolving of it by the percolating atmospheric waters have caused the immense local disturbance which we may observe wherever these middle eocene rocks are exposed to the surface and to the influence of weathering.

The coal-bearing beds of Much in the Bolan belong to this subdivision; indeed the outcrop of these beds is continuous from Harnai, *viâ* Mudgorge, Gandak, Spintangi, and then extends from Astangi to Much, the section across the eocene into the overlying Siwaliks being quite identical throughout. In 1880 I adopted the term "Ranikot beds" for them, comparing and correlating them with the beds of that name in Sind. I have not seen the latter myself, but I thought that both in stratigraphical position and lithological character they corresponded so closely with the Much beds that I could use the term in the same manner as we include in the word Talchirs, rocks of very differing character forming the base of the Gondwanas. Dr. Blanford, who has seen both Much and the Harnai development of the eocene series, prefers not to use the term Ranikot for the green shales and sandstones of the middle eocene, though admitting that they correspond very closely. I prefer not to use new and local names for geological horizons, when the approximate age of the same is known, and therefore am only too willing to drop the term "Ranikot beds," and shall continue to call them middle nummulitic in this paper.

For the same reason I do not adopt Oldham's name of Ghazij beds which he has given to this important horizon.

The general sequence of beds within this subdivision of the eocene is as follows, in *descending* order[1]:—

Horizon.	Description of beds.	Thickness in feet.
MIDDLE NUMMULITIC	6 Bright coloured shales with sandstone, which weathers a brick-colour.	200
	5 Brown sandstone; partings of shell limestone .	60
	4 Gypsum shales	30
	2 and 3 alternation of shales, sandstone, gypsiferous clays and coal seams.	370
	1 Greenish sandstone and shales, about . . .	800
	TOTAL, ABOUT .	1,460

[1] The numbers in this subdivision correspond with the numbers in Plate 2.

This series of beds is of some considerable importance, as it contains a large amount of coal just above the lower half of its thickness. Thin coaly partings and seams of a few inches in thickness are found at various horizons of the series, but they are frequently only of small extent laterally, and thin out rapidly. But in one horizon (2-3 in above section) at least two seams occur, parted by an irregular layer of shales, which are of great importance for Baluchistán. The seams have an average thickness of perhaps two feet, and it pays to extract the coal on scientific principles. The horizon is rather extensively worked between Dirgi and Sháhrág under the superintendence of Mr. Hope, and there is every prospect of further supplies, though not on a more extensive scale, being obtained from Sháhrág itself, where systematic mining will be commenced.

Coal seams.

In all sections between Dirgi and Harnai and above the middle nummulitic shales and sandstones, a very characteristic formation may be observed, namely a series of light-coloured limestones full of fossils, which stratigraphically and palaeontologically must be assigned an upper eocene age, and which Mr. Oldham has termed the Spintangi beds, so-called from a locality where these beds are strongly developed. I distinguished the horizon in 1880 as "nummulitic limestone" overlying the "Ranikot beds;" Dr. Blanford terms the same simply *upper nummulitic* and, as such, I shall speak of the subdivision in this paper. I do not see any necessity to distinguish this series of beds by any local name, since we know its exact geological horizon.

Upper Nummulitic.

The lithological character of the upper nummulitics is generally very constant; the greater thickness of it consists of light coloured grey or yellowish white limestones, sometimes with shaly intercalations, but containing fossils almost throughout its thickness. The series of beds is perhaps best seen (within the area under description) in the sections south of Harnai, where they seem to be developed in greater thickness than in the sections further west or north-west, but that may be due to the fact that in both instances the upper nummulitics are overlaid by the lower Siwaliks, and so may have suffered in some localities greater erosion than in others.

South of Harnai may be seen to perfection the very considerable alternation (in the upper portion of the series) of yellowish white earthy shales with a greyish white concretionary limestone. I noticed this rock-facies in the lower Bolan in 1880 and described it in Mem. Vol. XVIII, p. 30; lithologically it belongs to the same development as the concretionary limestone of the lower nummulitics (Chappar Rift, Wám Tangi, etc.), but I think it is more largely represented in the upper nummulitics. Similar rock is seen in the limestone beds of Sukkur and Rohri on the Indus (Kirthars of Blanford), where a peculiar red clay forms irregular masses and particles between the limestone nodules, which are often replaced by chert concretions with numerous fossils. This red clay reminded me of red clay inclusions in beds supposed to be representatives of deep-sea deposits.

Fossils are common throughout the upper nummulitics; they form a considerable collection and await determination.

The thickness of this subdivision of the eocene varies in the different sections; at Khóst and Sháhrág it certainly does not exceed 500 feet in thickness, but it may thicken out to quite 1,000 feet in the Harnai section. I doubt, however, whether it will be found of much greater thickness elsewhere.

Siwalik formation.—Next in importance to the eocene division of the tertiary system in Baluchistán is the immense thickness of beds of the Siwaliks, which range in age from the upper miocene to pliocene times. Large tracts of country in Baluchistán are made up of rocks belonging to this facies of the middle and upper tertiary system. I think it is quite possible that an unconformity will be found between the lower and upper portions of this formation, which so far I have not met with as a connected sequence. There are some considerable variations in the lithological character of these beds, but it is not difficult to divide them into the following subdivisions, each distinct enough to be recognized in most instances without any trouble.

Age.	Divisions.		Character of beds	Approximate thickness in feet.
PLIOCENE.	Siwaliks.	Upper.	(e) Buff coloured and grey sandstone with shales and gypsum in veins and flakes.	3,000 to 5,000
			(d) Grits and variously coloured clay and shales with gypsum.	1,500
			(c) Brick-red and reddish purple sandstone and shales; sandstone often mottled.	1,500 to 2,000
MIOCENE; UPPER		Lower.	(b) Grey, often greenish grey sandstone with shales, towards base calcareous grits.	700 to 800
			(a) Grits and ferruginous breccia; conglomerate of chert nodules. In the grits rolled specimens of *nummulites* often form regular layers.	50 to 100

The upper Siwaliks, though largely developed on that part of the frontier, are not found within the area described in this paper, whereas the lower beds of this facies form the greater mass of the hills which confine the "trough" along its southern side.

The boundary between the upper nummulitics and the lower Siwaliks is very marked indeed and nothing could be more in contrast than the white or ochre coloured limestones and the grey sandstones of the upper nummulitics with the ferruginous grit of the lower Siwaliks, which generally weathers a deep brown, almost black, and might be taken for a trap intrusion when viewed from afar off. The bottom bed of the Siwaliks is almost invariably composed of this grit; only here and there, dark yellow to brown ochreous deposits replace the conglomerate, but even then the boundary is very clear.

With this contact bed at the base, occurs locally a chert conglomerate of very peculiar nature. It is almost entirely made up of chert nodules, often of very large size, cemented together by a ferruginous matrix. Some of these chert nodules may have been derived from the upper cretaceous or lower nummulitic limestones, but I think the greater number of them come from the upper nummulitic beds, which in some localities (as for instance near Sukkur on the Indus) contain great quantities of chert concretions which yield well-preserved *foraminiferæ*. Immediately above

the bottom bed (which is of very insignificant thickness, though prominent in colour and lithological character) occur fine-grained grey and greenish grey sandstones with irregular beds of grits and calcareous gritty sandstone in which fossils, *i.e.*, mammalian and reptilian remains, are not scarce. They are most frequently found in the gritty parts of the formation, and they come out of the stone in very fair preservation.

Bones are found right through the lower Siwaliks, but I never obtained any but very poorly preserved specimens much above the lowest horizons.

Grey sandstones.

The grits and chert breccia at the base pass gradually into thickly stratified grey sandstone of the common pepper and salt appearance, which sometimes show a greenish tinge, in which case they are difficult to distinguish from the middle eocene sandstones. An occasional bed of reddish sandstone comes in, and these become very frequent near the upper boundary of the series (b) and finally pass into the great thickness of brick-red to purplish mottled sandstones (c) with shales. They have yielded some friable fragments of bones.

The beds of the lower Siwaliks form the scarp on the southern side of the "trough," and south of it, range on range appears to be composed of this formation. These ranges show true "scaly" structure, not monoclinal folds; the repetitions of grey with brick-red coloured sandstone seem to point to a system of parallel faults, and the lateral compression resulted in a certain degree of dove-tailing into each other of an otherwise moderate thickness of these two main subdivisions of the lower Siwaliks. If we looked upon this belt of Siwaliks as forming a continuous sequence of beds, we should have to assume a very much larger thickness for this formation than we are justified in doing. The upper Siwaliks are not represented in the country described in this paper, and I believe it will be found that a considerable unconformity divides the lower from the upper series, which are always met with in separate areas.

As far as parallelism of strata goes no sort of unconformity can be detected between the eocene beds and the lower Siwaliks in most of the sections northwest of Sháhrág. But apart from the fact that the upper eocene is developed essentially as a marine series of strata, whilst the Siwaliks, as their fossil contents close to the boundary show, is a fresh-water, probably lacustrine formation, there must also be taken into consideration the peculiar nature of the beds at the base of the latter. They are all of them such as form either in shallow water or close to the banks of a river or the shores of a lake. They are grits and conglomerates with thin beds made up almost entirely of the destruction of eocene rocks with their fossil contents rolled and worn.

Whilst there is no deviation from the parallelism of strata visible in the Khóst and Sháhrág valleys, we may observe splendid examples of the latter in the neighbouring area of Kach where lower Siwalik strata, with the bone grits at their base rest on the eroded edges of the cretaceous beds below. Similarly a distinct overlap and unconformity between the lower Siwaliks and the upper nummulitic limestone may be seen in the sections south of Nasak and Harnai.

Recent.

It is necessary here to mention also the very considerable deposits of recent conglomerates, grits and sandstone which mostly in the form of enormous fans occupy such large tracts in the "trough." They form terraces and fans gently sloping down from the high hills which bound the "trough" along its northern margin and have now been deeply cut into and eroded by

the present streams which drain the valleys. They form a thick covering over the great trough-like depression, and are eroded into V-shaped valleys by the existing drainage, which frequently exposes the much-contorted eocene beds below.

I did not observe any disturbance of these recent beds, such as is seen near the entrances of the Bolan, near the Nari gorge and along the eastern slopes of the Sulaiman range.

III.—SECTIONS.

Near the Chappar Rift.

Between Dirgi station on the North-Western Railway and the Chappar Rift the ground is most unfavourable for the geologist. The lower nummulitic limestone forms a very fine example of an anticlinal in the Chappar range, which is conformably overlaid by the green sandstones and shales of the middle eocene; between the Chappar Rift and Dirgi the actual contact is not seen, but south-east of the latter station, beds of the middle eocene may be observed in natural contact with the lower limestone, and this contact is conformable. Similarly north-west of the Chappar, much-crushed beds of the middle eocene subdivision rest evidently conformably on the limestone, but the hill-sides are far too much obscured by debris and slipped masses of rock to furnish clear sections. This part of the middle eocene is a continuation of the Mudgorge beds of this subdivision, and may be traced to the station of that name without interruption.

Dirgi.

The sections west and north-west of Dirgi are perfectly normal, but the disturbance is so enormous, that I did not attempt even to study the beds in detail. Coal-seams occur, and they might possibly be found to be part of one or at most two seams, but by faulting and folding the semblance of a number of seams has been produced.

Disturbance of strata.

The middle eocene beds, so conspicuous for their olive green to grey colour, with brown sandstones near the upper part are overlaid conformably by white or light grey limestone with *nummulites* and other fossils of the upper eocene, which again is overlaid by the Siwalik formations. The latter form the uppermost scarp of the range. The average dip of the whole sequence of beds is at an angle of 40° to 45° to south-west. The great disburbance which the beds have suffered is not only due to the natural folding process, which has affected all the strata in Baluchistán, and which in the first instance is probably the result of the lateral contraction of the area once occupied by the beds; it is also influenced to a very large degree by the chemical and other processes which have followed the wrinkling of the strata into mountain masses. Foremost amongst these processes is the change which these beds undergo, through the conversion of the anhydrite nodules and veins so common in the middle eocene, into gypsum, and the subsequent dissolving out of the latter by percolating water. The first leads to an expansion of the mineral and consequent distortion of the strata containing it; the latter creates cavities and leads to the slips which have altered the face of the hills. What with the distortion of these beds, which is bound to bring about minor wrinkles and folds where there is no great thickness of beds overlying and protecting the gypsiferous middle eocene subdivision, and the slips which must necessarily occur, where the angle of the scarps is considerable, the disturbance which has affected the surface of the middle eocene is immense, and it is not frequently possible to make out the true sequence of beds. Undoubtedly secondary folding, and even apparent unconformities between the sub-

divisions of the eocene, which are formed of such varying rocks, have been produced and may be traced in the valley above Dirgi; such can, in fact, be seen along the whole length of the "trough."

Mr. Jones on Dirgi.

The following notes were made on the Dirgi neighbourhood by Mr. E. J. Jones of the Geological Survey of India:—

"Ascending a stream, which comes down the hill side above Dirgi (north-west of it) one passes over a great thickness of the gray or olive green sandy shales, alternating with light green sandstones, which north-west of the station are seen to dip 50° S.W. A little further on (W. 10° N. from the station) there are some coal-seams, the dip being 70° S.W. near the base of the section, lessening to 30° S.W. near the top.

The section is in descending order:—

Description of beds.	Thickness. ft.	Thickness. in.
Dull pink shales of great thickness with green conglomeratic sandstone	2	0
Coal-seam	1	0
Shale	0	9
Coal	0	5
Shale	0	5
Coal	0	5
Shale	8	0
Coal	0	1
Shale	3	0
Coal	0	6
Fine-grained sandstone and shales, partly concealed, but about	20	0
Coarse soft sandstone, locally conglomeratic	17	0
Fine-grained sandstone	6	0
Shales	11	0
Coal	0	1
Grey carbonaceous shales	0	4
Good coal	0	3
Shales	0	8
Coal	0	6
Pyritous shales	0	9
Greenish do.	4	7
Carbonaceous shales	0	3
Great thickness of green shales	...	...

Above this section sandstones and shales are seen to continue some distance, with few thin seams of coal (none of over 1 inch in thickness). Further up still, there is a small coal-seam in shales dipping 40° S S.W, but it is very friable; it may be traced for about ¼ mile along the outcrop, when it is covered up by the talus. Immediately below this coal the sandstone contains numerous small bivalves. For some 70 to 100 feet sandstone and shales alternate, and they contain at several horizons thin seams of coal or carbonaceous matter. This series is overlaid by shaly beds of very prominent red, green and light grey colours. In a stream-bed south of Dirgi, near the station, the shales and sandstones dip 40° S.W., beyond which they roll a good deal, and finally dip 30° N.W., near which point I saw a carbonaceous band in the shales. Much disturbed beds follow with some coaly inclosures, overlaid by the highly coloured clay shales seen in the former section which in turn are overlaid by nummulitic limestone.[1]

Between Dirgi station and the railway bridge below, there are numerous exposures of thin seams of coaly matter in the shales; they are much disturbed and their dip varies all round the compass.

Close to the end of the railway bridge, on the right bank of the river, the dip is 40° N.W., whilst nearer the hill they dip about the same angle to south-east.

[1] The Upper Nummulitic limestone.

There is an outcrop of coal on the south side of the Uzdap Sháh anticlinal S.W. from the railway bridge; it is very poor and leafy and does not improve in lower depth. Two seams of coal can be distinguished about 50 feet apart, but the highly coloured clay-shales have slipped down from above, partly covering up the section. They appear now as if both underlying and overlying the coal series.

Mr. Jones on Hákim Khán.

Near Ka'la Hákim Khán, about 1 mile from the railway, coal traces may be seen along the face of the hill for about ¼ mile, though partially covered up by slips.

The following sections are taken from actual exposures and from the headings which have been driven into the hill-side to prove the coal [1]:—

Near the centre of exposure; No. 9 heading	ft.	in.	At the bottom of the heading 23′ from the surface.	ft.	in.	Bottom of No. 6 heading.	ft.	in.
1. Sandstone	2	...						
2. Dull green clay								
3. Sandstone	32	...						
4. Clay and shales	12	...	4 *Coal*	...	2			
5. Coloured shales	1	6	5.	...	7	5. Shales	...	...
6. *Coal*	...	6	6.	...	7	6. Leafy *coal*	...	8
7. Brown clay	...	3	7.	..	1	7. Shaly parting	...	1
8. *Coal*		...	8.	1	10	8 Good coal	...	11
9. Brown shales	1	...	9.	...	1	9. Shales	...	10
10. *Coal* with partings	...	10	10.	...	8	10. *Coal*	1	2
11. Friable sandstone	...	7						
12. Light coloured sandstone	8	3						
13. Shaly sandstone	6	...						
14. Shales with sandstone partings	11	...				The whole dipping 55°.		
15. Shales and shaly sandstone	84	...						

At the south-east end the section is at the bottom of the heading; dip 30° S.W.

Description of beds.	Thickness. ft.	in.
4. Clay shales	...	...
4*a*. *Coal* with a thin parting of shales	...	5
5. Shales	...	½
6. *Coal*	...	11
7. { Brown shales	...	9
{ Carbonaceous shales	...	5
8 *Coal*	...	10
9. Brown shales	...	6
10. Good *coal*	1	...
11. Sandstone	...	...

The section in another heading close to No. 9 is dipping 55° to S.W., and is as follows in descending order:—

Description of beds.	Thickness. ft.	in.
4 to 5 { Grey shales	...	...
{ Carbonaceous shales	...	5
{ Grey shales	...	6
6. *Coal*	1	4
7. Coaly shales	...	4
8. *Coal*	1	5
9. Clay shales	...	1
10. *Coal*	...	9
11. Sandstone	...	...

[1] Mr. Jones does not mention it, but I assume that the section is a descending one.

Section north-west of No. 9 heading dipping S. 20° W.

Description of beds.	Thickness. ft.	in.
Grey shales	...	...
Carbonaceous shales	...	8
Grey do.	...	6
Coal	...	5
Carbonaceous shales	...	2
Coal	...	9
Carbonaceous shales	...	1½
Alum do.	...	3
Coal	...	3
Carbonaceous shales	...	2
Coal	...	10
Shales	...	3
Coal	...	11
Sandstone	...	...

Khóst Sections.

More important are the sections across the Khóst valley, both as regards the geology which is clearer, and also l ecause some of the best seams of coal of the eocene division of Baluchistán are found there and are being mined.

About 2 miles noith-west of Khóst station, and almost opposite Buzgai Rága, a much-disturbed section is *in situ*; the base of the hill slope, which forms the right (south-west) side of the valley, consists of green sandstone and shaly beds characteristic of the middle eocene. The dip is steep to south-west. They are overlaid by shaly greyish brown sandstone, concretionary, showing at places concentric structure. About half-way up the hill side brownish grey sandstone with calcareous la}ers appears, which is the typical rock of the middle of this subdivision of the eocene. Towards the base of this sandstone series, three considerable thicknesses of sandstone aie alternating with shales; the former are about 20′ thick each, and are equidistant from each other. The two lower horizons of shales are traversed by fissures and joints filled with gypsum, and this mineral forms flakes and nests throughout the formation. The shales between the three sandstone horizons contain several poor seams of coal, very irregular in thickness, and it appears from some abandoned workings that they frequently thin out very rapidly. The best and steadiest seam or group of seams is near the upper part of the second sandstone horizon and is descending:—

Description of beds.	Thickness. ft.	in.
Shales	...	...
Coal	...	½
Sandstone	...	4
Coal	...	3½
Carbonaceous shales	...	6
Coal	...	9
Carbonaceous shales	...	8
Coal	...	3
Calcareous shales	...	4
Sandstone	...	...

This is the Khóst coal horizon, which further south-east improves greatly. The dip is steady, 40° to south-west.

The hill-side is greatly obscured by debris and slipped masses, besides which

some minor faults evidently repeat the section, for as I ascended I found, after a small thickness of shales, the same series of sandstone repeated, which passes into a considerable thickness of coloured shales, and above it follow some 150 to 200 feet of brown to olive coloured sandstone on which rest conformably the grey fossiliferous upper nummulitic limestones; which again are overlaid by the grey, and further on by the purplish red sandstones of the Siwaliks.

Higher up a fault which runs parallel to the strike of the hill range, cuts off the section and the upper portion of the upper nummulitic limestone with the great mass of the Siwaliks is repeated.

Mr. Jones on Khóst.

Mr. Jones had also examined this last section, and has found several repetitions of it caused by local slips and faulting; he says that "there have been two distinct landslips on the face of the hill, so that the coal-seams are repeated three times, thus giving the idea of a large number of seams. The section according to him is as follows:—

Description of beds.	Thickness. ft.	in.
1. Variously coloured clay shales	...	...
2. Dark-greenish blue shales	...	...
3. *Coal* with shales (mostly the latter)	6	...
4. Shales	40	...
5. Good, bright *coal*	1	...
6 Shales	12	...
7. *Coal*	...	9
8. Shales	70	...
9. Sandstone	10	...
10. Shales	3	...
11. Carbonaceous shales	1	6
12 Shales with a *coal*-seam, 1" thick	10	...
13. Sandstone	10	...
14. Carbonaceous shales	...	2
15. Shales with calcareous concretions	1	...
16. Pale-coloured shales	...	
17. Shales with two *coal* partings of 5" each	2	2
18. Shales	10	..
19. *Coal*	...	3
20. Shales	60	...
21. Sandstone	10	...
22. Shales	20	...
23. Sandstone	9	...

Below this are seen the variously coloured clay shales which have been let down by a fault, and the whole section is repeated.

The ground immediately to the south of the Dabak section (and W.S.W. of Buzgai Raga) is very similar to the area last described. Very little of the beds is seen *in situ*, owing to the numerous minor faults, and the enormous mass of debris which covers the hill-sides. The climbing of the latter is exceedingly easy, though rough, but very little is seen of the lower and middle parts of the section. I could distinguish, though not so clearly, the three sandstone zones alternating with green arenaceous shales, which latter seem to be in greater thickness in this section. They are traversed by a network of veins of gypsum, and there is much surface disintegration and bulging out of the shales in consequence.

The sandstone beds both below and above the coal-seams are full of organic

remains; plant-impressions, stalks and carbonaceous matter, besides a great number—whole nests in fact—of a species of *unio*, thus clearly showing the fresh-water origin of the horizon.

The upper portion of the gentle slopes which are composed of these sandstones, and the shaly beds above them, is almost entirely covered up by the debris from the upper nummulitic limestone, which forms a distinct cliff, a precipitous scarp facing northwards. It is composed of a light-coloured limestone full of fossils, *corals, foraminiferæ, gasteropods* and *bivalves*. This upper eocene subdivision forms the highest part of the crest and part of the dip-slope, which descends down the other side of the range. It appears to be about 150 to 200′, thick, but it is most probable that this does not represent the entire thickness, as it has no doubt been extensively denuded before the lower Siwaliks were deposited on it.

Above this upper nummulitic limestone follows the ferruginous grit with chert nodules, and irregular layers of impure limestone chiefly made up of rolled *nummulites* from the limestone below, and this is overlaid by grey grits (with fossil bones) and greenish grey sandstone of the lower Siwaliks. The great hill-mass (7,810′) west of the ridge is made up of the purplish red and brown sandstones of the Siwaliks. The dip of the upper nummulitic limestone, which is the same as that of the beds below, where not locally disturbed, is 33° S.W.

A very curious concretionary limestone grit, which weathers a dark rust colour, forms a small thickness between the upper nummulitic limestone and the coal-horizon below, but I have not met with this bed in the sections further south-west.

South of the Khóst Rest-House.

The hill-side south of the rest-house at Khóst shows a similar section to those further to the north-west of it, but the coal-bearing horizon is better developed. There seem to be four distinct horizons of greenish grey sandstone, which contain numerous *unio* and some plant-impressions which are alternating with green shales, in the lowermost horizon of which the workable coal-seams occur.

Above this sandstone and shale series follow highly coloured, pink and greenish clays and arenaceous beds with sandstone partings.

The sandstone and shales series with coal-seams does not exceed 350′ in thickness apparently, whilst the highly coloured clays and shales above may be about 500′, but that is only a rough estimate, as the numerous slips and small faults put a correct measurement quite out of the question.

The highest beds of the section are, as in the former cases, sandstone and grits which are conformably overlaid by the richly fossiliferous upper nummulitic limestone.

About 2 miles south-east of the Khóst station this limestone is overlaid by the grey sandstone of the lower Siwaliks, which have yielded some rather good and well-preserved fossils in the grits near their base; the upper beds are, as already seen in the sections north-west of Khóst, formed by the purplish red mottled sandstone and shales, also containing bone fragments, but they are less well preserved than those found in the lower beds. Together this Siwalik series forms high and steep scarps along the entire crest of the range south of Khóst, presenting dip-slopes towards the south-west on the other side.

South of Khóst Station.

Almost due south of Khóst station the face of the cliff is much faulted, but several large and intact blocks have slipped down on the north slope, which are now mined for coal, and which so far

have yielded the best fuel. There are two series of mines separated by a tongue of debris which occupies a shallow valley between spurs of middle eocene. The spur on the north-west side of this tongue of debris shows about the same section as the hill-side south-west of Buzgai Raga; the lowest beds which are exposed—in fact the middle horizon of the middle nummulitic—consist of greenish-grey sandstones, with reddish grits and sandy beds. They pass into highly coloured clays and shales with gypsum, which are overlaid conformably by the fossiliferous upper nummulitic limestone. The chief coal-horizon is found in the sandstones and shales below, and I believe that there is only one good seam, consisting of a very steady bed of about 2 feet of coal, with a parting of gypsiferous clay shale of varying width. Above and below occur insignificant seams, generally only of a few inches in thickness, which frequently are found to thin out rapidly, and then generally pass into a ferruginous layer, which sometimes shows some thin partings of leafy coal. The dip varies from 40 to 45° S.W. and S., and the workings are all on to that seam. There are several minor faults which have repeated some of the beds several times over, which makes this subdivision of the eocene appear to be of much greater thickness than it really is.

Siwaliks near Khóst.

The upper nummulitic limestone, which forms a conspicuous light-coloured band along the hill-side, is overlaid by the ferruginous and chert beds with concretions (pisolitic) of clay iron ore. This passes into a ferruginous conglomerate, which locally becomes a coarse grit; it is overlaid by and interstratified with grey Siwalik sandstone. The grits often form patches in the sandstone which contain fossils,—fragments of bones and teeth in excellent preservation. The total thickness of the grey sandstone with the grits below can scarcely be more than 300 feet.

The highest part of the range is formed by reddish purple and rust-coloured sandstones and shales, also containing fossil bones, which rest conformably on the lower beds, but are of much greater thickness. I estimated the thickness south of Khóst at not less than 800 to 1,000′, but this does not represent the total development of the lower Siwaliks, which is enormous. The dip is about 40° S.W. and S.

The Khóst collieries which are south-east of the tongue of debris mentioned, are situated in a wedge of the middle nummulitic which has been let down by a system of parallel faults. Indeed, this has been proved not only by the features on the surface which are somewhat obscured, but by the fact that in several of the workings it has been found that the coal suddenly nips out,—owing no doubt to having been crushed against a fault plane.

Ali Khán.

The range on the right side of the valley shows much disturbance between Khóst and the gorge south-west of Ombo. A series of small faults showing no special feature, save that they are directed generally from south-east to north-west, have let down the hill-side in steps, which gradually bring the upper nummulitic limestone down to the level of the river (see plate I, fig. 1), which is the case south-west of Ombo. The result is that the otherwise normal section of the middle nummulitic has been repeated several times, and mining is rendered much more difficult thereby; several apparently fine outcrops of coal may be seen along the hill-side, one south of Ali Khán being specially remarkable owing to the fact that the local disturbance which the beds have suffered have resulted in a most intricate folding of the beds and with them that of the coal-seam, which being closely folded and dove-tailed, measures at one place not

less than 14 feet, the actual and original seam with its centre parting of shales being not more than a little over two feet.

About 2½ miles south-east of Ali Khán the beds sweep round the scarp of the range and up the low pass of Spar Báz leading to Shangal, where another small fault may conveniently be observed,—this one of south-west to north-east strike. Considerable crushing may be observed eastwards of the fault, and the upper nummulitic, which forms a good landmark in the section, is seen to form the lowermost rock in the river-bed. The entire crest of the range is formed by the lower Siwaliks, the grey sandstone with the purplish red sandstone and shales above. The continuation of the section downwards must be looked for north of the range, amongst the low hills and the undulating country which form the base of the trough and immediately west of Ombo, the watershed between the Khóst and Ombo rivers. The greater part of the valley is covered by the enormous fans which descend from the Khaliphát range, but recent denudation has worn them into long strips and has formed long V-shaped channels in the great thickness of gravels and recent sandstone which compose the fans. Further away from the hills, in the low reaches between Khóst and Púnga, the middle nummulitics are exposed in patches surrounded by recent deposits, and are found to be extensively folded, crushed and dipping in every direction. Thin coal-seams are found in these beds, but they are far too much disturbed to be of any great economic importance; where seams of this kind are seen, they can and often are followed up by native contractors, but in such disturbed areas scientific mining is altogether out of the question.

Patches of such rocks are seen here and there in the deeply eroded channels which are formed in the fans, and north and north-east of Khóst some thin coal-seams are seen in the green shales and sandstones of the middle nummulitics.

Mr. Jones has examined the Khóst sections and in his MS. report has given the following section which is exposed in the eastern Khóst ravine, just below the variously coloured shales which overlay the main coal-horizon of Khóst:—

Description of strata.	Thickness. ft.	in.
1. Hard brown sandstone	20	0
2. Light green shales	3	10
3. Deep red shales	3	3
4. Green shales	47	11
5. Brown sandstone with shaly partings	5	0
6. Grey clays	3	0
7. Calcareous sandstone (near the top of which are 9″ of carbonaceous shales, thinning out rapidly)	10	0
8. Shales	8	0
9. Soft brown sandstone with partings of shales	12	0
10. Very light green shales, arenaceous near base	40	0
11. Shaly sandstone with clay nodules and partings of shales, pass into (10)	29	0
12. Alternation of greenish grey arenaceous shales and sandstone	30	0
13. Carbonaceous layer	0	1½
14. Dark shales	1	4
15. Parting of ferruginous shales	0	4
16. Dark shales	0	11
17. Light green clay shales	17	5
18. Coaly shales	1	0
19. Bluish green shales	2	0

	Description of beds.	Thickness. ft	in.
20.	Calcareous brown sandstone	7	0
21.	Greenish shales	23	0
22.	Sandstone, fine-grained	11	0
23.	Greenish shales	4	2
24.	Carbonaceous layer	0	1½
25.	Dark brown limestone	0	2
26.	*Coal*	1	0
27	Greenish shales with purplish patches	3	7½
28.	*Coal*	1	0
29.	Brown decomposed pyritous shales	0	2
30.	Carbonaceous layer	0	2
31.	Variously coloured purple, green and brown shales	7	0
32.	*Coal* (upper seam)	1	1
33.	Clay shales (pyritous)	0	6½
34.	*Coal* (lower seam)	1	2
35.	Clay shales, similar to (33) with coaly matter	0	4½
36.	Bluish grey shales, carbonaceous	0	10½
37.	Pyritous greenish brown shales	8	0
38.	Fine-grained brown sandstone with partings of shale	86	0
39.	Dark coloured shales	24	0
40.	Sandstone	2	0
41.	Light greenish grey shales	68	0
42.	Shaly sandstone, passing into (41)	2	0
43.	Arenaceous shales passing into (42)	35	0
44.	Sandstone with partings of shales	77	0
45.	Calcareous layer	0	6
46.	Thin-bedded sandstone	4	0
47.	Bluish green shales	102	0
48.	Shaly sandstone	10	0
49.	Greenish shales with calcite veins	56	0
50.	Alternation of shaly sandstone and shales	35	0
51.	Greenish sandstone	7	0
52.	Alternation of dark arenaceous shales and sandstone	89	0
53.	Shaly sandstone with partings of shales	29	0
54.	Arenaceous green shales	21	0
55.	Alternation of sandstone beds and dark shales	107	0
56.	Green shales	56	0
57.	Sandstone with partings of shales	20	0
58.	Greenish gray shales	50	0
59.	Sandstone	15	0

The recent deposits of the river interrupt the section here, but at places the sandstone and shales may be seen to underlie the recent gravels.

Háji Kats.

North of Khóst and near Háji Káts there is a thin seam of coal in the shales which dips 30° to north. It shows a good deal of crushing, is about 4″ in thickness, and is traversed by calcite veins.

Sháhrág area.

The sections of the eocene division which are exposed between Harnai and Sháhrág are perhaps the best in this valley. As shown in pl. 1, figs 2, 3 and 4, the sections do not consist of simply one normally ascending sequence of the eocene and Siwaliks, but we may there observe several folds of considerable size. These folds to a large extent have helped to determine the topographical contour of the country, and, indeed, we see

all along the north slope of the chain of hills which form the south-eastern continuation of the Khóst range, a series of lower hill ranges, running parallel with the ormer. They are formed of crushed folds of middle nummulitic beds with Siwaliks. North-west and west of Sháhrág these folds disappear beneath the recent conglomerates, and only here and there much-denuded remains of the middle nummulitics show as patches, overlaid or surrounded by the recent formation.

The section south-west of Sháhrág is a continuation of the Ombo sequence of beds. Near the defile south-west of the latter place, the upper nummulitic limestone is seen actually at the level of the river, with the Siwaliks overlying it. From that point the upper nummulitic limestone is seen to ascend and sweep round the contour of the hill-mass south of Sháhrág; the middle eocene shales and sandstone, which near Ombo are covered up by the river gravels, form a section below the upper nummulitic limestone, gradually widening as I followed it up eastwards. The coal-horizon which is found about half way up the middle eocene, must, therefore, have been covered up by recent deposits south-west and south of Ombo, and as near as can be they should be *in situ* at the base of the hill, due south of Sháhrág. A boring at the base of the hill-side south of Ombo or south of Sháhrág ought in both cases to reach the coal within a very short depth; near the latter locality the coal should be nearer the surface than at the former.

The Púnga stream passes from north to south through a broad belt of eocene beds, the exposures of which are interrupted for considerable distances by the sub-recent and recent conglomerates which are locally of great thickness. But enough is seen of the beds to be able to say that all that part of the eocene, which lies north of the defile 3½ miles south of Púnga, is greatly disturbed,—so much so, indeed, that it would be impossible to follow up every one of the numerous minor folds into which the strata of the middle eocene have been twisted. In its main features, the section one or two miles east of this stream is simple enough; it consists of a great synclinal which occupies the ground between the railway line and the stream which feeds the Siáh Dád river on its left (or east) side, followed south by an anticlinal, or more correctly speaking what was once an anticlinal, the arch having been completely denuded away. South of that the eocene beds and the overlying Siwaliks dip south or south-west (see. pl. 1, fig. 2).

Considering this section in detail the structure is slightly more complicated; the synclinal south of Púnga is not much disturbed, and that chiefly near its eastern termination (west of Nasak), but the denuded anticlinal south of it is immensely crushed. Where the upper nummulitic limestone with the great thickness of Siwaliks above normally overlays the middle eocene shales and sandstone, the latter show little disturbance, except imediately near the surface; but where these upper beds have been denuded away, as is the case within the area of the anticlinal, there the middle eocene, full as they are of gypsum in veins and nests, have undergone an extraordinary amount of local folding and disturbance. Not only have they been crushed and compressed into folds owing to the expansion, following the absorption of water by the anhydrite below the surface, but the latter having been converted into gypsum, is gradually dissolved out by the action of water, and so extensive landslips are seen all over the surface of this undulating country. The entire area shown on the map south-east of Sháhrág and coloured as middle eocene has been thus affected, and is therefore useless for measuring the section, or for economic (mining) purposes.

In many of the side streams of the Siáh Dád river, parts of the same section is repeated many times, and probably some twenty or thirty coal-seams could be recorded, which all of them turn out to represent different folds of, perhaps, at the most, two good-sized seams. In a side stream which joins the Siáh Dád from the right (west),—coming from Sháhrág in fact,—very good examples of folds, both synclinal and anticlinal ones, may be observed,—proved to be such, not only by the constant repetition of the same bed (notably one, a calcareous sandstone with *turritella*), but there are also several distinct folds seen in the bed of the stream. To measure the section by the ordinary means, *i.e.*, with a measuring tape, would have been absolutely useless; I had to do my best to arrive at an approximate measurement of the section by surveying the steeper slope (see pl. 2) of the upper nummulitic and the middle eocene exposed on the scarp of the southern range.

The *lowest* beds are nowhere sufficiently well exposed to allow a correct measurement, but I think my estimate of their thickness will be found to be approximately correct. The following is the section shown on the hill-side, on the east or left side of the Tangi (defile) in descending order:—

Divisions.	Subdivisions.	Description of beds.	Thickness.
Pliocene and Upper miocene	Lower Siwaliks	(12) Sandstones and earthy shales, generally of purplish grey to red colour; often mottled brown and grey.	
		(11) Grey sandstone of true Siwalik type, gritty irregular beds with fossil bones.	
		(10) Grits, conglomerates and chert breccia.	
Eocene	Upper Nummulitic	(9) Massive greyish and white limestones with fossils	250
		(8) Greenish and yellow olive-coloured shales, sometimes light grey, alternating with light grey concretionary limestone full of fossils	75
		(7) Sandstone, shales and conglomerate, weathering black, made up chiefly of pebbles of lower nummulitic limestone. Chert nodules amongst them	150
	Middle Nummulitic	(6) Bright coloured shales, red and greenish white, with calcareous sandstones, weathering a deep brick colour	200
		(5) Brown sandstone, weathers brick colour, with limestone beds, which are full of bivalves	60

Divisions.	Subdivisions.	Description of beds.	Thickness
Eocene . .	Middle Nummulitic .	(4) Greenish brown sandstone alternating with bright green and grey shales with veins and nests of gypsum	30
		(3) Shales, sandstone and two coal-seams	220
		(2) Alternation of grey shales and sandstone with beds of shell limestone near base of series; thin partings of leafy coal .	150
		(1) Green sandstone and shales; gypsum, base not exposed. Thickness possibly	800
		Total Thickness of middle and upper eocene	1,935

These beds dip about 55° south, but there is a good deal of rolling, and some of the beds are raised up to an angle of from 70° to 80°.

Fossils are rare and badly preserved in the middle nummulitic beds of Sháhrág, excepting in thin calcareous sandstone beds in the series (2) and (5), which are full of well-preserved *Gasteropods*, amongst which there are a number of genera; also bivalves are met with, which form thick layers composed entirely of the shells of one species only.

In a sandstone horizon immediately above the coal-seams of the series (3) occur large numbers of a species of *unio*, often forming regular nests.

The coal-seams are very few in number, and seldom exceed a few inches in thickness, and often turn out to be nothing else but carbonaceous shales; only two seams appear to be good enough to repay regular mining operations. They occur rather high up in series (3), and are both of about the same thickness, varying from 2 feet to 2 feet 3 inches with thin clay partings. It is possible that they may turn out to be one and the same seam, simply repeated at very short distances by faulting, but it is very difficult to pronounce a decided opinion on the subject, the hill-side being too much obscured by debris.

They are close together, and form a horizon which may be followed for a long distance both south-eastwards and in a west and north-west direction. At present some contractors obtain a certain amount of good coal from shallow workings, but I understand that the North-Western Railway intends to work these seams in a more systematic manner. The uppermost beds of the middle nummulitic subdivision, which are of considerable thickness, do not contain coal-seams, but are chiefly remarkable for the considerable amount of gypsum which occurs in veins and nests.

Upper nummulitics.

The boundary between this subdivision and the upper nummulitics is not very distinct at Sháhrág. A sandstone series with conglomerates seems to define the base of the latter; but excepting this, the two subdivisions pass from one into the other gradually, as the

bright coloured clays and shales show which also occur with and above the sandstone. Higher up limestone beds appear and gradually replace the sandstone; they are full of fossils, amongst which an enormous number of *nummulites* of several species are remarkable. Where the rock is weathered, the ground is simply covered by the weathered-out *nummulites*, so that frequently, and for long distances, one walks on nothing but these *foraminiferæ*. In the upper portion of this series ochre-coloured to olive green shales are intercalated, but are not thick enough to be noticed from afar off. Fossils seem scarcer in them than in the limestone beds adjoining. A very predominant rock in this subdivision is the nodular limestone, which I first noticed in the Bolán in 1880,[1] but which is found both in the lower nummulitic limestone and in this subdivision, varying from each other but very slightly.

Siwaliks.

Immediately above the upper nummulitic limestone and with bedding parallel with that of the latter, follow the lower Siwalik strata. The ferruginous breccia (10) at the base also occurs here, locally associated with grits and a bed of chert nodules, above which follow the grits (with teeth and bones) and grey sandstones (11) of the common lower Siwalik type. These pass gradually into the red and greyish purple sandstones and shales (12), and both together form the precipitous scarp which constitutes the main mass of this range. From the crest of the latter one may view ridge on ridge formed of the lower Siwalik sandstones, all dipping south-west, with a dip-slope in that direction and a scarp turned to the north-east. Most probably these sandstones do not represent a continuous sequence of strata, but a series of parallel faults combined with the dovetailing (scaly structure) so commonly seen where sedimentary deposits have been squeezed into narrow strips, have produced the peculiar contour of these hills, and have given the lower Siwaliks the semblance of an enormous thickness of beds.

Other sections near Sháhrág.

There are no great changes seen in the sections further south-south-east, and certainly the scarp shows the same sequence of beds, and that in a fairly normal —*i.e.*, little disturbed—position, and even if the outcrop of coal (quite close to the small ravine which runs into the main stream) is not always seen, being covered up by debris, still the coal is there, and will be found either by sinking a shaft down on it, or, if a low enough spot can be found, by driving a level into the hill-side below the coal horizon.

North-west and immediately adjoining the described section, the beds are more disturbed. Near the point where the path from Sháhrág descends into the river close to the Tangi, the middle nummulitic beds are exposed on both sides of a small spur; a coal-seam of about 2′ 3″ is *in situ*, and crosses the spur almost at a right angle. A number of thin partings of shale divides the seam into beds of coal not more than 6″ to 7″ each. The dip is very steep to the south, but what there is of coal can of course be taken out easily enough, and, in fact, when I visited the spot it was being removed by a native contractor.

Up the hill slope which stretches west and north-west from near the Tangi, a similar section is seen as described above; it seems a good deal disturbed near the surface, but it is probable that the sequence of beds will be found to be normal at some

[1] Mem. Vol. XVIII, p. 30.

depth below the exposure. The coal horizon runs all along this hill-slope near its base; the only indication of it near the surface consists of two thin seams, respectively 6 and 7 inches thick, divided by a sandstone parting of 1½ foot thickness, the whole enclosed within a series of shales and thin sandstone beds. Gypsum is found throughout the shales and even in the coal-seams. Immediately above this horizon is an impure calcareous sandstone containing many well-preserved *gasteropod* genera represented by numerous species, whilst a sandstone immediately below contains *unio* which form whole banks and shell-beds.

North of this hill-slope and in the Siáh Dád stream itself nothing but very highly disturbed beds are seen, dipping almost in every direction; in fact the friable shales and sandstones of the middle nummulitics have been crushed and disturbed wherever the superincumbent strata have been removed by denudation. Seen from the hill south of Sháhrág, which commands a fine view of the section south of Púnga (see pl. 1, fig. 2.), the structure appears to be plain enough.

Section south of Púnga.

Immediately south of Púnga rises a low range, which extends far to the south-east, only broken through by the Nasak and Harnai streams; this range consists of a shallow synclinal of middle and upper nummulitics and is capped by lower Siwalik sandstone. Denudation has excavated deep ravines into this range, and here and there reduced it to very narrow dimensions indeed, as for instance near Harnai. It is best seen near Púnga, where it is a conspicuous range, south of which may be seen a much-disturbed sequence of the middle nummulitics which dip north and south near the Púnga synclinal and the "Sháhrág" section respectively (see fig. 2.). This disturbed area is the site of an anticlinal, the arch of which has been denuded; at the present moment this anticlinal, the general features of which are partly preserved, has been replaced by a number of smaller and crushed folds, consisting of the shales and sandstones of the middle nummulitics.

In such a highly disturbed area it is only natural that we should meet with numerous exposures of coal-seams, some even of encouraging thickness, as the coal horizon near the middle of this sequence of beds has been repeated many times over through folding and faulting. That this is so, is proved by the structure of the beds exposed in the deeply eroded stream-beds, where numerous secondary folds may be observed. Frequently there are most encouraging coal-exposures met with within these folds, and surface workings have been commenced. I need scarcely mention, that as long as there are coal outcrops, like Khóst or Sháhrág (near the Tangi) left, it could not pay to mine for coal in disturbed localities, such as those in the low hills south of the Púnga synclinal. Where good-sized seams crop out, and can be reached without difficulty, native contractors may be allowed to take out the valuable mineral, but regular mining operations should be confined to such localities as we find 2½ miles south-east of Sháhrág station.

As already shown, the hill-range south of Púnga is formed by a simple synclinal; the main mass of the range is no doubt made up of Siwalik sandstones, but near the base of it the eocene beds crop out. The southern slope of the range is affected by a good deal of minor disturbance merging into the crushed anticlinal alluded to already, but the northern slope is a normal sequence of beds, all dipping about 25° south.

Close to the highest point of the ascent between Sháhrág and Nasak, called Púnga Ghát, is a burial-place, not far south of which the upper nummulitic limestone

is *in situ*, forming a scarp facing north. This exposure of limestone may be traced along the whole face of the cliff in both directions; westwards it is seen to follow the contour of the hill range, and is continuous with the band of limestone which crops out below the Siwaliks along the southern slope of the synclinal In the Nasak direction it follows strictly the contour of the range, where it forms a steep scarp south of the railway line to beyond Harnai; this scarp is continuous but for the gap created by the Nasak stream which has eroded a defile through the range. The strata forming this range dip steadily south-west at an angle of 25° to 45°. The limestone scarp is overlaid by the lower Siwaliks. West and below the upper nummulitic limestone (7 to 9) I observed that the bright coloured clays and green shales and sandstones of the middle nummulitic subdivision form the undercliff between the Púnga Ghát and Nasak.

Near the former locality itself nothing is seen of the beds which underlie the upper nummulitic linestone, but much-distorted beds of the middle nummulitic are *in situ* and form the low hills, which protrude from the sub-recent conglomerates and fan deposits which stretch away to the foot of the Wangi and Khaliphát ranges. The beds which I observed in these isolated hills are much disturbed, but can easily be recognized as the green shales and sandstones of the middle nummulitics. In some places fossils (chiefly *gasteropoda* and *oyster* banks) are common, and here and there thin coal-seams and carbonaceous layers are found in the series. Mr. Jones describes a few seams from the hills north-east of Sháhrág, which, if less disturbed, would no doubt be valuable. As they are, they are only fit to be worked by natives in native manner.

Coal below Púnga.

Mr. R. D. Oldham has already suggested, without specifying any particular spot, that a boring in the Púnga Ghát would reach the coal horizon. I may add to this, that almost any spot near the Púnga Ghát might be selected, were it decided to attempt such a boring, and the only difference in sites would consist in the depth at which the coal horizon of Sháhrág would be struck. A boring about 100 yards south of the gangmen's house on the ghát ought to meet the coal-seams about 700′ below the surface. This depth would lessen as one moves the bore-hole northwards, but on the other hand the possible chances of finding the middle nummulitics much disturbed further away from the hill-slope would lessen the certainty of finding the coal-seams.

Ragani.

West of Púnga Ghát a steep ravine leads down into the Ragani stream valley. The ghát itself—*i.e.*, the highest part of it—is formed by the recent and sub-recent conglomerates, which in this ravine are seen to be of great thickness. They generally show quite horizontal bedding, and of course cover up unconformably the beds of the middle nummulitics; the latter have been exposed in the Ragani stream, a tributary of the Nasak river.

On the right side of the valley the scarp of the range is composed of the upper nummulitic limestones as already related, below which the crushed beds of the middle nummulitic shales and sandstones crop up. Near where the path from Púnga Ghát reaches the Ragani valley, very little is seen of the green shales, etc., beyond some exposures of crushed beds of it beneath the sub-recent conglomerates, but further on, near Ragani itself, the middle of the subdivision is *in situ* with its coal horizon. There appear to be about five seams divided by partings of clay shales, the total thickness of coal and shales not exceeding 6 to 7 feet. Very irregular

the seams seem to be, for some of them may be seen to thin out and to pass into dark grey shales within the distance of a few feet. It looks a most unpromising seam to work, but it might be further explored by either boring south of it or by driving a level into the hill-side below the outcrop of the coal; the latter, however, is so near the bottom of the valley that not much of the seam could be worked without interference from groundwater. The dip of the coal-seam and accompanying beds is about 40° south-west.

The bright-coloured shales and clays with sandstone beds (6) overlie the coal series of Ragani, above which the upper nummulitic limestone rests conformably.

The same shales and clays, deep red and greenish grey with bluish bands, are *in situ* on the left side of the Ragani valley, north-west of the village; they are mostly covered up and obscured by the sub-recent conglomerates. But enough of them is seen to warrant the assumption that the whole of the middle nummulitics will be found to be greatly disturbed below the fan deposits, and that the fragments of seams which are met with in the crushed sections of the Ragani valley would be worthless for purposes of regular mining, although some of them might be good enough to be dug out by native miners.

Section west of Nasak.

A section drawn at a right angle across the ranges between Ragani and Nasak (see pl. 1, fig. 3) reveals a structure very similar to that of the section south of Púnga Ghát. There is first a synclinal fold, — the south-eastern prolongation of the Púnga Ghát synclinal, only with this difference, that here it widens considerably, and excepting that they are much cut up by denuding streams, the beds appear to be less disturbed than south of Púnga Ghát.

The Siwalik synclinal is rather more than two miles wide, and near its southern flank, where the beds dip north-east (the point of observation is 3½ miles west of the village of Gachin), the contact between the lower Siwaliks (brown grits) and the upper nummulitic limestone beneath is most distinctly unconformable. The Siwaliks dip about 50° to 55° north-east, whereas the limestone below is vertical or nearly so, its dip decreasing further south, until a north-easterly dip has set in. Of course the unconformity between these two divisions may be an apparent one only, and the divergence of dip be explained by the enormous compression and disturbance which the area has suffered, but the examination of the section further south shows clearly that there is a great unconformity between the two series of strata, as indeed one might suppose that such must occur when a fresh-water deposit follows a purely marine one.

A very fair section is obtained on this line about 2½ miles south-west of Nasak, where a small stream has cut through the beds south of the synclinal. The beds between the upper nummulitics and the normal sequence of strata on the southern or main range, are practically an anticlinal, the dip being north-east and south-west respectively, but as is the case south-east of Sháhrág, so also here, the upper part of the anticlinal having been denuded, the middle nummulitic shales, etc., which form the greater part of the section have been exposed to chemical and mechanical action, and thus we see them now puckered and folded in a most complicated manner. There is a good deal of recent debris, which obscures the section at places, but leaving unnoticed the numerous minor disturbances, inversions and faults, I could observe not less than two, perhaps three, distinct folds within the belt of middle nummulitics.

The upper nummulitic limestone is of the same thickness as along the scarp near Ragani, and overlies a series of soft alum shales with sandstone partings, which may be of about 600 to 800 feet in thickness. They pass conformably into a horizon of shales and sandstones, which contains coal-seams. I noticed two coal-seams besides one or two carbonaceous layers. The upper coal-seam is about 1′ to to 1′ 2″ in thickness, whilst the lower coal horizon appears to be a continuation of the one worked at Khóst and Sháhrág. It consists of two seams of 1′ 8″ and 4″ of good coal, divided by a shaly parting of 1′ to 1′ 6″. The beds are much disturbed and crushed, whilst the dip of the seams is nearly vertical, and the whole series is traversed by numerous gypsum veins.

These seams occur near the base of the valley which runs parallel to the strike of the anticlinal. Close to the coal seams, apparently *above* them, occur shales and calcareous sandstone beds, full of *gasteropods*, which horizon was also observed south-east of Sháhrág. From the base of this valley to the crest of the range south of it the section is again an ascending one. Sandstone shales and above it the greyish white and pink clay shales of the Sháhrág section may be observed to gradually pass into a great thickness of beds which belong to the upper nummulitic subdivision It is an alternation of light coloured grey limestone, full of *nummulites* and other fossils alternating with yellowish green shales. Many of the limestone beds possess the peculiar nodular structure already often noticed, and with the latter occur numerous chert concretions full of *foraminiferæ*. This development of the upper nummulitics is lithologically precisely the same as that of the "Kirthar" limestone of Sukkur and Rohri, and evidently belongs to the upper portion of this subdivision, which is fully represented in the present section, but has been denuded away in the neighbourhood of Khóst and Sháhrág. This being so, explains the unconformity of the lower Siwaliks over the eocene seen further north-east in the same section; the former rest upon different strata of the upper eocene in different localities, and we may, therefore, assume that a considerable erosion of the upper nummulitics has taken place in early Siwalik times.

The entire thickness of the upper nummulitic limestone with shales cannot be less in this section than from 1,200 to 1,500 feet. They form the somewhat steep slope of the main range along the southern flank of the section, and are overlaid by the typical grits and chert conglomerate with grey sandstone of the lower Siwaliks followed by a great thickness of red sandstone.

Scarp between Nasak and Harnai.

As already stated elsewhere, the upper nummulitic limestone forms the scarp south-east of Nasak as far as Harnai. South-east of Nasak Station the road passes over a low pass, and through a cutting in recent conglomerate. Immediately east of it the road (and also the railway line) crosses a low saddle formed by an anticlinal of middle nummulitic shales and green sandstones (with traces of coal-seams), flanked on each side by upper nummulitic limestone. Some short distance further to south-east, coal-seams are *in situ* near the road-side; they consist of a number of thin seams of leafy coal with many partings. The total thickness of coal available cannot be more than about 2′ 6″, but it is so much divided by shaly partings that it is quite worthless. This sequence of grey friable shales, clays, and coal-seams forms together a series, about 15 feet thick, which dips 25° to 30° south-south-east and is underlaid by brown sandstone. The hill-side is too much obscured by debris to afford opportunities for a closer examination, but I estimate the thickness of the

middle nummulitic subdivision which lies above this coal horizon at about 600′ to 700′, and is then conformably overlaid by upper nummulitic limestone. About 7½ miles south-east of Nasak Station the Harnai stream makes a sharp bend to the north-east, and near it the coal (in very poor leafy seams) occurs again in the bed of the stream itself. From this point I traced it along the scarp on the right side of the valley, gradually rising to a higher level; it dips 28° south. Above the coal-seams brown ochreous sandstone with impure clay nodules occurs, which has furnished some marine fossils, mostly small bivalves. Below the horizon with coal, I noticed a bed of grey shell limestone, patchy with red ferruginous stains, full of bivalves (valves generally open). The section above the coal to the upper nummulitic limestone is highly disturbed, but presents no special features to be noticed.

The Harnai Section.

The section from Harnai to the spur of the Torghar—*i.e.*, from north-east to south-west—is, as may be supposed, very similar to the section west of Gachin already described. It crosses a synclinal (see pl. 1, fig. 4 and pl. 3), passes then through a much-disturbed anticlinal, and becomes an ascending section again until the Siwalik sandstones of the Torghar spur are reached.

South of Harnai the scarp of the range already described shows a very fair section from the upper nummulitic limestone to the lower portion of the middle eocene. It has a sharp crest with a fine dip-slope of 25° south to south-south-west. The main features of the sequence of beds are in descending order as follows:—

Upper nummulitic.—Considerable thickness of dark grey to reddish limestone with *echinoderms, bivalves* and *nummulites* throughout, the same facies seen also at Púnga Ghát, Khóst, etc. It cannot be more than 180′ to 200′ thick and forms a steep scarp facing north, with a dip-slope of 25° to south.

Immediately below this limestone are sandstone beds of a rather strange character; they are dark brownish grey and resemble the Siwaliks. Throughout its thickness ferruginous concretions occur, which weather out in irregular-sized nodules. In this sandstone, but seldom in the highest beds of it, occur sub-angular fragments of chert. They are formed both in layers and singly.

Below this thickness of sandstone is a bed of brown ochre-coloured calcareous rock, which also contains numerous sub-angular fragments of chert, being in fact partially made up of them; locally it could be called a breccia. It is of no great thickness and passes below into sandstone; it is dark grey to reddish in colour, and resembles somewhat the red Siwalik sandstone, but is more gritty. Near the base of this series is a conglomerate, which is made up of chert nodules and limestone pebbles, cemented together by grey sandstone. Though differing in some respects from beds in the upper nummulitics, it must be recognized as the lowest series of the latter (see series 7 of the Sháhrág section). The conglomerate indicates an unconformity, but neither at Sháhrág nor here could I see any divergence in the dip between the conglomerate beds and the shales of the middle nummulitic below.

Middle nummulitic.—Below the above, I observed the green and whitish grey and pink coloured shales with sandstone partings which seem to constitute a very constant horizon of this subdivision.

Below these are gypsiferous shales, generally of greenish colour, with green and brown sandstone and clay beds. In the lower strata of this series a few thin seams of coal occur. The dip is 28° south-east, and as this block of beds is not

much disturbed, the coal might be extracted with a fair chance of success. The most promising seam is about 2 feet 6 inches in thickness, but with a parting running along its centre. The coal could be got at by a tunnel at or near the base of the range in the same manner as at Khóst but probably there would not be so much of it available as at the latter locality, for the present outcrop itself is not far above the base of the range. Below the coal horizon, green to brown sandstone and shales crop out, the lowest beds of which are not seen.

South of the crest of the range, the section is, as indicated in fig. 4, a synclinal of upper nummulitic limestone which incloses crushed beds of Siwaliks. The latter show conformity along their northern boundary, but overlap denuded beds of upper nummulitics along the southern flank of the synclinal. The base beds of the Siwaliks are strongly developed; the ferruginous grits and chert bed are seen on both sides of the narrow valley, and associated with the lowest beds of the grey sandstone overlying them. I noticed again the typical grits with bones.

Near the unconformable contact of the Siwaliks and nummulitic limestone, I noticed once more the peculiar deposit immediately above the base beds of the Siwaliks,—namely, a calcareous irregular band, made up almost entirely of rolled *nummulites* and fragments of the same,—all no doubt derived from the upper nummulitic limestone. This deposit is irregular in thickness, but in some places is most conspicuous from afar off, owing to its dark brown colour.

Following this section further south, and crossing the southern arm of the synclinal, I observed the upper nummulitic limestone composing the same, which dips at an angle of some 50° to 60° below the Siwaliks, and forms a steep scarp, which faces south. The descent into the valley beyond leads over the upturned beds of the upper nummulitic limestones, sandstones and conglomerates,—finally over much-crushed beds of the middle eocene with carbonaceous layers, but no coal as far as I could see. It is quite possible that the coal thins out in these sections, as it undoubtedly does immediately west of the Harnai seams, which pass laterally into a ferruginous grit with carbonaceous layers. Near the base of the valley I observed shales with numerous fossils, chiefly *gasteropods*, which is probably the same horizon seen further north-west in the Sháhrág section.

The undulating valley, which is a continuation of the Sháhrág-Gachin anticlinal, shows a very disturbed structure, and it appears most probable that there are several secondary folds and reversions within this valley, of which I give a diagrammatic rendering in pl. 1, fig. 4.

Above these folds and forming the hill-slope of the spur of the Torghar which faces northwards, there is a fine, and I believe very extensive, section of the upper nummulitics *in situ*. The base beds are formed of limestones and nodular limestone beds with light greenish shales, such as are seen also in the sections north-west of this one. Higher up come sandstones and green grits, with sandstone beds of very altered and Flysch-like character which I have not met with within the upper nummulitic subdivision in Baluchistán before. The whole is once more overlaid by nummulitic limestone on which the Siwaliks rest in normal order. The green grits and sandstones might possibly represent the lowest beds of the upper nummulitics, and they resemble somewhat the beds of that subdivision met with in the Sháhrág section, and the sequence of eocene immediately south of Harnai. Some of the sandstone beds in this section show concentric weathering, very similar to the shales and sandstone of Flysch type which I noticed in the hills

between Cherát in the Peshawar district, where they are also associated with eocene beds.

Gachin Sections.

The sections further north-west, near the group of villages of Gachin, are very similar to those of Harnai; they simply form continuations of the diagrammatic section, fig. 4, particularly as regards the south-western portion of it.

Structure of hills north of Harnai.

In previous paragraphs in this paper I have mentioned that the range of the Chappar, which stretches to the east as the Khaliphát mountains and beyond, is made up chiefly of beds belonging to the lower nummulitic limestone, which form a simple anticlinal, much cut into by eroding streams, but on the whole showing its structure perfectly. The green shales and sandstones of the middle eocene overlie this limestone conformably, though along the margin of this range this feature can scarcely be observed; first, the middle nummulitics have generally been covered up by sub-recent conglomerates and fan deposits as shown on the map, and secondly, because where an actual contact is visible, it is usually a disturbed one, because the softer shales and sandstones have naturally suffered much more than the compact limestones of the lower nummulitic, when the whole area was compressed into folds, and also because aided by denudation and other causes, the shales, etc., of the middle nummulitic have followed the laws of gravity and slipping off the highly incline- anticlinal, are now seen collected in a mass of complicated folds at the base of the latter. It is, therefore, easily explained why little can be learned by studying the contact of the two subdivisions of the eocene along the base of this range. South and in front of the eastern prolongation of the Khaliphát ránge, and between the Púnga river, and east of the Wám Tangi, another and very distinct anticlinal extends, in structure precisely the same as that of the more northern one. Along the greater part of its southern margin it is flanked by fans and sub-recent conglomerates, whilst in the synclinal between the two anticlinals middle eocene beds are seen to overlie the lower nummulitic limestone (see pl. 1, fig 2).

Details.

I examined first the south-eastern and eastern termination of the range. Between it and Sháhrág several low hills and isolated ranges stand out conspicuously from the gently sloping plain, which is formed of the fan deposits already mentioned. They are merely remains left of the numerous folds into which the middle nummulitics have been laid. I found the strata composing them dip irregularly in all directions; coal-seams appear in the mass of shales and green sandstones, but the bedding is far too much disturbed to permit their being regularly mined for.

Near the western termination of the southern anticlinal and about 1½ miles south-west of Wangi, a mass of shales and sandstones belonging to the lower beds of the middle nummulitic form a low range close to the anticlinal, and there the conformable position of the beds over the limestone may be seen. They consist almost entirely of a series of friable olive green shales with a few partings of calcareous sandstone. The two villages of Wangi are situated close to the mouth of a defile of that name, which not only cuts through the limestone anticlinal, but also deeply down into the sub-recent gravels and fan deposits, which latter form magnificent, almost vertical-faced cliffs, several hundred feet high. At Wangi it is clearly seen that the range really consists of two anticlinal folds, which further east merge into one only. The stream which runs through the

northern Wangi, defile rises in the neighbourhood of Ziarat in the Khaliphát anticlinal, where it forms deep ravines, cuts through the Wangi defile, and flowing south has eroded a narrow and vertical-sided channel through the limestone, afterwards continuing its erosion of the fans south of the range, where it becomes the Nasak river. It affords an illustration of a river which could not have scooped out the defile through the anticlinal whilst the latter was formed; the sub-recent gravels south of the "Tangi" are absolutely undisturbed, and yet have been cut into by the river, the defile through it being an absolute continuation of that which passes through the limestone,—with vertical sides and sharply defined course.

The upper beds which form the anticlinal are dark coloured *crinoid* and *coral* limestone, in which numerous fossil traces appear; *nummulites* are common. The sequence of beds is generally the same as the one observed in the Chappar rift, but fossil traces become scarcer as one descends in the section. In the upper portion of it, beds of nodular limestone are frequent, of the kind seen also in the Chappar rift; this is a recurring lithological feature, and beds of this kind are not only seen in this subdivision, but also in the upper nummulitic, where I first noticed them.

The lower beds seen in the Tangi are perhaps more flaggy in character, or at all events, many flaggy layers occur within the dark limestone, but I saw no *shales*. Before reaching the north end of the defile, the beds descend rapidly towards the north, completing the anticlinal. The dip is 60° north and the beds of limestone finally disappear below the horizontal sub-recent conglomerates.

The synclinal between the two limestone anticlinals is divided into two drainages. The western one escapes east of Peri through the Wangi defile, whilst the eastern one breaks through the Wám Tangi. The western valley (of Peri) is mostly filled by sub-recent deposits and fans; there are traces only of the midde eocene shales near the northern margin of the valley. Near Shavzgi the ground rises, and a low pass leads into the Wám drainage; the middle nummulitic green shales and sandstone (with coal traces) are seen to form the pass and occupy the greater part of the synclinal valley on the other side, only patches of sub-recent deposits obscuring the beds, which are highly disturbed and crushed.

The Wám river breaks through the anticlinal of limestone and affords a very good section. The latter is seen to form a simple arch, minor disturbances and local faults excepted; the upper beds are dark limestone, full of minute organic remains, and some well-preserved *nummulites*. Broken, the rock shows no kind of organic structure. In the upper part of the limestone series, nodular beds are common, similar to those of the more western Wángi defile. In the solid limestone beds I observed good examples of cleavage, and the whole mass of this subdivision of the eocene is jointed throughout.

Belemnite beds.

Near the centre of the Tangi and close to the base of the arch, I noticed a band of thin-bedded red and pinkish limestone, below which the beds become flaggy and alternate with shales and marls of light green colour; the lower horizon of it is a fine olive-green marl with the usual conchoidal structure which reminds me of some of the upper cretaceous horizons which I have seen in Baluçhistán.

This I take to be Mr. Oldham's *belemnite* horizon; indeed the latter occupies the same relative position in the more eastern Miráb Tangi according to him and

seems lithologically very similar. I have not been lucky enough to find fossils in these shales.

CONCLUDING REMARKS.

It only remains to add a few words on the economic value of the area. This, of course, consists in the large amount of coal which is available in the more or less constant horizon of the middle nummulitic subdivision. Most of the outcrops have either been worked or are sufficiently tested to prove the usefulness of the coal as regards quality and the limited thickness of the seams, and it is certain that even after the complete exhaustion of the Khóst collieries there will be a very large amount of coal left in other sections of the field. I will not enter here into the composition of the coal; this has been done already[1] by other observers. Mr. Jones has also attempted to compute the quantity of coal available, but he has certainly much under-estimated the latter. The fact is, no estimate, even approximately correct can possibly be arrived at, which would be of the least practical use. The whole basin of the "trough," including the entire hill-range which bounds it along the southern rim, with probably a large area south of it, is part of the field and contains seams of coal. If only the Khóst seams are taken as examples and the amount of coal calculated on the thickness of these seams and the area of the basin, no doubt a fairly accurate idea of the amount of coal *present* in these strata would result; but that is not the amount actually available. The greater portion of the basin is broken up by faults, folds, and some of it has been carried away by denudation, so that only a small proportion of the total coal is available for mining purposes, and of these portions the exact limits are not known. In the above paper I have given a description of the distribution of the seams, and also indicated in outlines which I consider the most promising localities for opening works, after Khóst is exhausted or nearing that stage.

Amongst the best of these localities is the cliff, 3½ miles south-east of Sháhrág Station, with the area immediately adjoining it. This will undoubtedly offer as good chances as did the Khóst workings, and the locality is near enough, the line of railway to be worked cheaply. Next to Sháhrág in importance, I consider the cliff between Púnga Ghát and Harnai; there the seams are good, but the outcrops are too low down the hill-side, to allow the same process of mining to be adopted as at Khóst and Sháhrág. The workings would be soon below the level of the ground-water, and therefore pumping would have to be resorted to, which would increase the cost of the output considerably.

Still more difficult to work, on account of the underground-water, would be mines established on the Púnga Ghát, or north of the river near Ali Khán, were it decided to bore in these localities for coal, which most probably would be met with not far below the present surface.

[1] *Records, Vol. XXII, Pt. 3, p. 149.*

Notes *on the* Geology *of a part of the* TENASSERIM VALLEY *with special reference to the* TENDAU-KAMAPYING Coal-field; *by* P. N. BOSE, B.Sc., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With two Maps [1].)

SECTION I.—PREVIOUS OBSERVERS.

Dr. Helfer, 1838.

Mergui has probably been visited by more geologists than any other part of Burma. The earliest explorer was Dr. Helfer, whose second report (the only one I have had an opportunity of seeing) was printed in 1839.[2] It contains an account of an overland journey from Moulmein to Mergui.

With regard to the coal in the Mergui district, Dr. Helfer observed several outcrops of it above Tirok Chhangh in the Great Tenasserim Valley. He observes, however, and rightly, that none of them "promised to be of practical use, the quality being either inferior, of considerable specific gravity, intermixed with numerous iron pyrites, or the seams very inconsiderable."[3]

Dr. Helfer was, however, very enthusiastic about his find of coal in the Little Tenasserim Valley, about five days' journey above the town of Tenasserim. He thought it combined all the desiderata required "respecting quality, quantity, and easy access." He considered this coal to be destined to supply the whole of India. It is to be observed that he was not aware of the Tendau-Kamapying coal, the subject of our exploration last season.

Tremenheere, 1841.

The next report is that of Captain Tremenheere, which is dated August 1841.[4] Though dealing chiefly with tin, it incidentally mentions the coal mine near Tendau. The Tendau-coal would, therefore, appear to have been discovered some time between 1838 and 1841.

Captain Tremenheere also speaks of extensive beds of "manganese ore" between Therabwin and Tagu. The ore was, however, subsequently found to be akin to graphite in composition, and was called Tremenheerite by Piddington.

Oldham, 1855.

Dr. Oldham paid a visit in 1855 and submitted a comprehensive report[5] on the coal and tin of the Mergui district. He describes the deserted coal mines at Tendau which had been worked twelve years previously and notices the occurence of excellent coal north of Tendau at Heinlat and Kamapying.

On the Little Tenasserim, Dr. Oldham found that the fine descriptions given of the coal there by Dr. Helfer were quite unsupported by facts. He says that "out of a bed or beds which on the surface look like a bed of coal of more than 4 feet

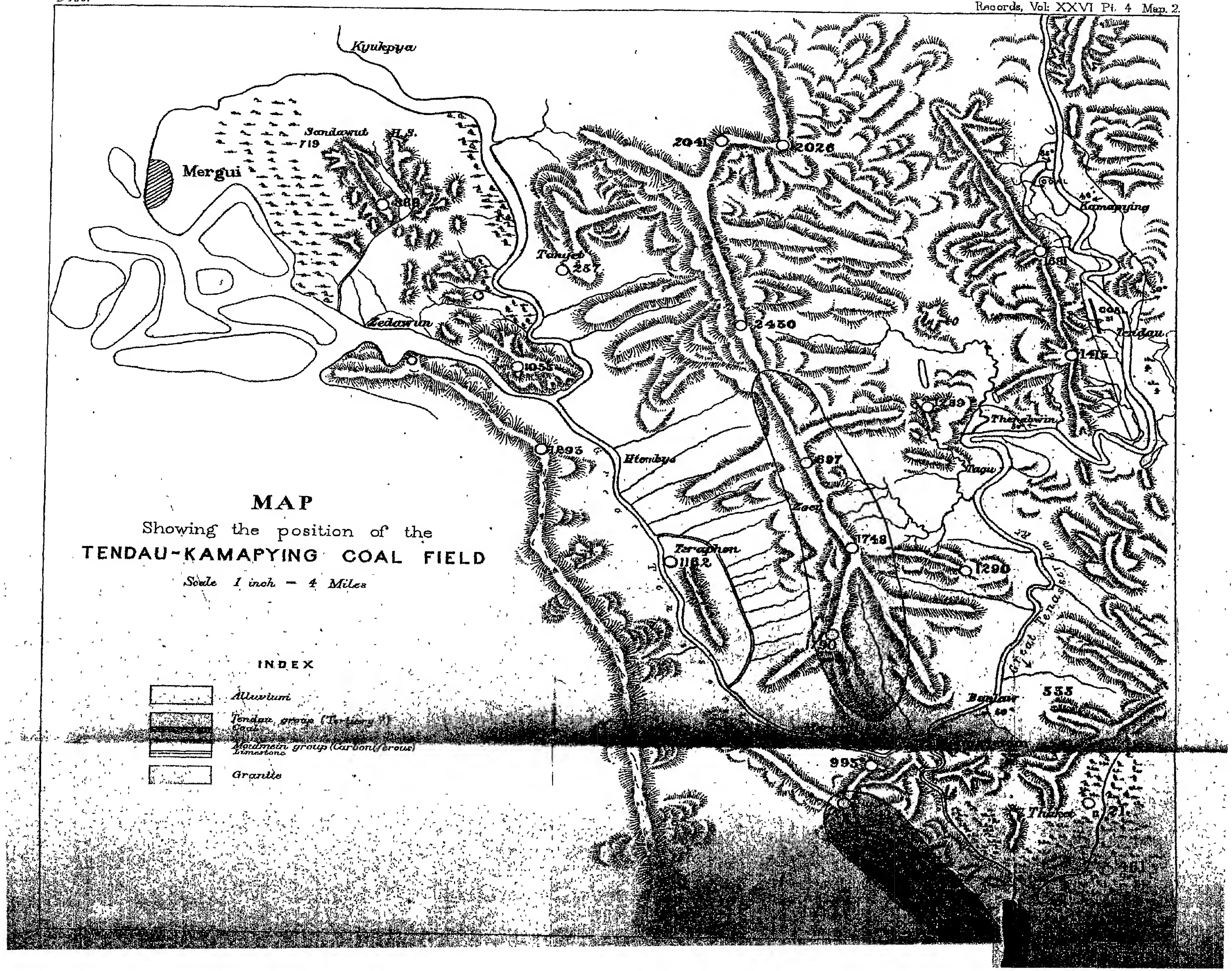
[1] The boundaries of the coal area in Map have been laid down by my colleague, Mr. P. N. Datta, Assistant Superintendent, Geological Survey. The topographical features in Map 2 have been compiled from the old map of Lieut. Bagge and from tracings courteously furnished by the officers of the Survey of India of their last season's work as it was in progress This map is therefore of an entirely provisional character. The patch of granite which has been mapped in south-west of the village of Tenasserim is from information.

[2] Reprinted at the Government Central Press, Calcutta 1875.

[3] *Op. cit.*, p. 36.

[4] Reprinted in "Geological Papers on Burma," p. 350.

[5] Reprinted in "Geological Papers on Burma," p. 375.


MAP
Showing the position of the
TENDAU-KAMAPYING COAL FIELD
Scale 1 inch = 4 Miles
INDEX
Alluvium
Tendau group (Tertiary ?)
Coal
Moulmein group (Carboniferous)
Limestone
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H.S.
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697
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Tagu
Great Tenasserim
Banlaw
555
993
Thakat

thick, there is in reality not more than 18 inches, frequently much less, of good coal, and this not in a continuous deposit but in irregular patches." [1]

Theobald, 1855.

Mr. Theobald appears to have accompanied Dr. Oldham. He was sent to examine some coal which had been reported by Dr. Helfer to occur above the great rapids of the Tenasserim. He found that it occurs in small nodular strings, not more than an inch in thickness, and by no means continuous, having therefore no practical value whatever.

Fryar, 1871.

In 1871, Mr. Mark Fryar, a Mining Engineer, was engaged by the Burma Government to report on the mineraliferous localities of the Tenasserim division. He has a short reference in his report to the coal at Tendau. He managed to dig from the mud and water of the river a sufficient amount of coal to make a large fire, and from the way in which it burnt, he thought that if required as a fuel on the coal-field or within a short distance of it, the coal would prove to be very valuable.[2]

Hughes, 1889-92.

The prospecting operations under Mr. T. W. H. Hughes in the Mergui district had special reference to tin. During the season 1891-92, however, the coal on the Htiphanko at Kamapying was explored.[3]

SECTION II.—GEOGRAPHY.

1. *The Tenasserim river.*—The Tendau-Kamapying coal-field is situated in the valley of the Great Tenasserim river, which has its source in the Tavoy district. After running nearly north and south for about 200 miles (measured in a straight line) it joins the Little Tenasserim at the old town of Tenasserim. Thence the river takes a westerly to north-westerly course, and divides into two important channels. The main channel to which the name of the river is restricted flows in a general north-westerly direction, and has its debouchure near the town of Mergui. The other channel running nearly south to north and falling into the sea at Kyuk Phya is called after this village. Both of these channels are navigable without any serious difficulty at all times of the year for vessels drawing about 6 feet of water as far as Banlaw, a distance by the main channel of about 50 miles. The influence of the tides is felt as far at this place, though the rise of water during the lowest neap is very slight. The highest spring-tide reaches about 14 miles further north, as far as Therabwin.

The river was found to be at its lowest from the middle of February to the middle of March. Even then, however, I succeeded with careful piloting in taking the launch *Ataran* drawing about 3 feet of water, as far as Therabwin during high spring-tide. Above Therabwin the river is full of shallows and rapids, and is navigable only for vessels of small draught between December and March.

Watersheds.—On either side of the Great Tenasserim (between its source and the town of Tenasserim) there is a hill-range running parallel to it,—that is, in a general north-south direction. It is observable, that the principal physical features of the Tenasserim division—the chief rivers and hill-ranges and the coast line—all

[1] "Geological Papers on Burma," p. 389.
[2] "Geological Papers on Burma," p. 419.
[3] Records, G. S. I., Vol. XXVI, pt. 1.

take this direction, which coincides with that of the dominant strike of the rocks constituting the country.

Of the two hill-ranges just mentioned, that to the east of the river forms the boundary between Siam on one side and the districts of Tavoy and Mergui on the other. It forms a well-marked watershed; the rivers rising from it on the Siam side flow into the Gulf of Siam, and those on the Tavoy-Mergui side run into the Mergui Archipelago. The hill-range to the west of the river forms a minor watershed,—the streams which have their source in it on the east side falling into the Great Tenasserim. Neither of the ranges rises to any very great heights, within the district of Mergui no peak being known higher than 2,500 feet.

3. The Great Tenasserim Valley.—The valley between the two ranges just mentioned is what may be called the Upper Tenasserim Valley. The Tendau-Kamapying coal-field is situated in this valley.

Alluvial flats.

The main ranges on either side of the river send out spurs in all directions, which give the valley a hilly character. There is, however, usually a variable stretch of alluvial flat just bordering the river.

Population.

The entire valley is very thinly peopled. The district of Mergui is greatly under-populated. The density of population per square mile according to the last census is 9·44. In the serial order graded by density, it occupies the thirty-third place, having only three districts below it in the whole of Burma.[1]

The Upper Tenasserim Valley is one of the least dense parts in the district. The population diminishes as we go up the valley. Within the coal-area, from Tendau to Kamapying, measuring about 30 square miles, there are probably not more than 50 houses with 250 souls.

Climate.

The mean annual rainfall of the town of Mergui is 183·7.[2] The rainfall of the Upper Tenasserim Valley will not be less than this figure. We had fine weather for two months and a half only, from the beginning of January to the middle of March. This fineness also is to be qualified. The whole valley used to be enveloped in mist till 9 or 10 o'clock in the morning. During the five months we stayed in the valley (December to April), I doubt if there were as many bright mornings. From the middle of March rain began to fall, and not unoften in heavy showers and accompanied by strong gales.

History.

Tenasserim, which gives its name to the southernmost administrative division of British Burma, was a large and important city when the country was in Siamese possession. It has now dwindled into a small village with probably not more than 400 inhabitants. It was founded by the Siamese in 1373 A.D. In 1759 the Tenasserim Valley was taken from the Siamese by the Burmese King Alom Pra. After the Burmese conquest, the Siamese, who were the principal occupants of the valley, deserted it and went over to Siam. The country has not yet recovered from the effects of that depopulation. It became British territory in 1855.

[1] Report on the Census of Burma (1891), p. 15.

[2] Report on the Census of Burma (1891), p. 7.

SECTION III.—GEOLOGICAL SKETCH.

1. *Moulmein Group.*

(*a*) Lithology.

Variously coloured clay rocks and sandstones in different degrees of mixture and of alteration form the predominant constituents of this group. There is one kind of clay rock which being dark and compact simulates the appearance of basalt. There is another kind of a lighter colour in which fragments of felspar and of granite being interpersed give it partly the appearance and character of tuff. Conglomerate is rare. I met with it in only one place, on the island just opposite Mergui, where it is developed in massive beds. There are a few bands of limestone of a highly crystalline character. It occurs in highly precipitous, jagged, bare ridges which form a most attractive feature in the scenery of the country. In these ridges occur caves[1] of various dimensions. Some I measured on the Great Tenasserim and the Lenya rivers were from 50 to 150 feet in breadth, and 60 to 250 feet in length.

There are also bands of carbonaceous shales with occasionally thin and variable seams of much-crushed, lustrous, graphitic-looking coal. These shales sometimes occur in close proximity to the limestone, as at Therabwin. At one locality above the great rapids of the Tenasserim I found the shales in superposition on the limestone.

The carbonaceous shales just mentioned are very widely distributed. They occur at various places in the Upper and Lower Tenasserim Valley—at Therabwin, Bankyot, Tagu, Thaket, Marton, etc. They are also known in the districts of Tavoy and Amherst, considerable tracts of which are constituted by the group under description.

(*b*) Disturbance.

The prevailing strike varies between a few degrees on either side of north and south. The dips are rather high, being seldom lower than 45° and sometimes as high as 80°. The beds are often found to be contorted. In the Upper Tenasserim Valley, on the west side of the river the dips chiefly point westward, and on the east side they were mostly found directed eastward, so that the main Tenasserim Valley would appear to lie along a denuded anticline.

(*c*) Age.

The only rock in the group which has yielded fossils is the limestone. It being highly crystalline, the fossils cannot be extracted without great difficulty. After some search in the neighbourhood of Therabwin I succeeded in getting together a small collection. It consists of the following well-marked carboniferous forms which have been determined by Dr. Noetling, the Palæontologist of the Survey:—

Schwagerina blanfordi, sp. Nov.
Lonsdaleia salinaria, Waag. and Wentz. sp. indet.
Lithostrotion, sp. Nov.

[1] It may be mentioned that thick deposits of the excrementa of bats cover the floors of these caves, and the stuff may be, and to a small extent is, utilised.

Aræpora, cf. *ramosa*, Waag. and Wentz.
Polypora, cf. *biarmica*, Keyserl.
Productus, cf. *sumatrensis*, F. Rœmer.
Athyris sp.
Spirifer sp.
Bellerophon sp.
Pleurotomaria, aff. *durga*, Waag.
Murchisonia sp.

Dr. Oldham, who called the group under consideration after the town of Moulmein, met with a similar assemblage of fossils in the limestone at the well-known caves near that place.

There can be no doubt of the carboniferous age of the Moulmein group, on the supposition, of course, that the limestone from which the above fossils have been obtained is an integral portion of it. I must say that I have scarcely any doubt on this point, though the evidence is not quite so conclusive as might be desirable.

2 *The Tendau Group.*

(*a*) Area and Lithology.

It occupies an area of about 30 square miles between Tendau and Kamapying, and is important as the group in which the workable coal of the district occurs.

Towards the base of the group occur shales and sandstones. The latter are medium-grained and reddish coloured, and were noticed to underlie the shales at the Chá Mitwe stream (near Tendau), the only place where the base of the group is well exhibited.

Shales.

The shales are variously coloured from greyish white to black, the darker colours being indicative of the proximity of coal which will be described in detail in the next section. They were encountered only on the western side of the river; and there, too, were not continuously traceable. Being of economic importance they have been roughly indicated on the map by a deeper shade of the colour appropriated to the group. The shales thin out to the east and appear ultimately to disappear altogether in that direction, as they do not reappear on the eastern side of the synclina basin.

Conglomerates.

Superposed on the shales are found conglomerates with interbedded sandstones and shales. The conglomerates are coarse, sometimes extremely so, the constituent pebbles measuring a foot or so in diameter. The pebbles are never well rolled, sometimes indeed they preserve their angularity to such an extent that the rock has more the appearance of a breccia, than that of a conglomerate. Amongst the pebbles are those of hard, compact clay-rocks belonging to the Moulmein group. The matrix of the conglomerate is more of a clayey than of a sandy nature. The sandstones interbedded with the conglomerates are massive, soft, and false-bedded.

(*b*) Disturbance.

The Tendau beds have been disturbed so as to form a syncline, those on the western side of the river dipping eastward, and those on the eastern side dipping in the reverse direction.

The strike in the northernmost part of the area is in a north-east—south-west direction. But it changes on the Heinlat stream, whence to Tendau it maintains a north-north-west—south-south-east direction, which is nearly the same as that of the strike of the "Moulmein" beds. It is remarkable how the disturbing forces, whatever they may have been, have continued to act in the same direction during so many ages. The dips are scarcely ever lower than 20° and are never higher than 40°; 30° may be taken to be the average dip.

(*c*) Age and Mode of deposition.

Uncomformable relation to the Moulmein group.

The Tendau beds rest uncomformably on the denuded edges of the Moulmein strata. At the boundary on the western side of the river the latter invariably dip westward, but on the eastern side they usually dip eastward. Besides, the dips of the younger group are not so high as those of the older.

Age.

The Tendau group is, therefore, evidently younger than the Moulmein. Some plant-fossils (mostly Dicotyledenous) and some fish-remains have been obtained from the shales belonging to the former group. Their exact determination, however, is a matter of the greatest difficulty. All that can be said is, that the age in all probability is tertiary.

The deposits of shallow-water origin.

That the deposits under notice were of shallow-water origin is abundantly apparent from the false bedding of the sandstones, and the great predominance and excessively coarse character of the breccia conglomerates. The Tendau-Kamapying beds extend for only about a mile or so on either side of the Tenasserim, and the length of the area occupied by them does not exceed 15 miles. There can be scarcely any doubt that they were laid down in a lake-like expansion of the then Tenasserim Valley, the physical configuration of the ground at the time of their deposition being much the same as at present. The material of the deposits was derived from the disintegration of the hills which still bound them in.

3. *Alluvium.*

The alluvial deposits in the Upper Tenasserim Valley consist of clay or loam resting upon sandy and gravelly beds. The former is usually coloured brownish and its thickness varies from 10 to about 40 feet. But the exact thickness of the latter could not be ascertained. A few borings were let down in the alluvial ground near Therabwin. But after passing through the loam, as soon as the rods came to the sandy and gravelly strata, the progress was slow and ultimately *nil*, or even negative. Sand and gravel filled up the hole as fast as it was made, or even faster, as they sometimes came up with some force, somewhat in the manner of an artesian spring. The same difficulty was experienced with borings and diggings at Tendau and at Kamapying. Boring after boring, and pit after pit, had to be given up, as with the appliances at our command scarcely any progress could be made through the troublesome sands.

The alluvial clay is more or less ferruginous and is at places cemented into a lateritic rock. Its vesicular character was in some cases found due to the agency of burrowing animals. Laterite due to the alteration of older rocks is also found.

Both kinds of lateritic rocks abound in the valley, though they are nowhere of any great thickness.

The alluvial deposits are found to dip, though at very small angles. They would thus appear to have been slightly distuibed in recent times.

SECTION IV.—THE TENDAU-KAMAPYING COAL IN ITS ECONOMIC BEARINGS.

1. Extent of the Coal.

From the last section it is clear that there is coal of two different ages in the Tenasserim Valley, one belonging to the Moulmein (carboniferous) group, and the other to the Tendau-Kamapying group, which is in all probability of tertiary age.

Coal of two ages.

The former coal is the more widely distributed of the two. It has repeatedly raised delusive hopes of workable fuel from the time of Dr. Helfer, when attention was first directed to the mineral resources of the Tenasserim division, until the time of Mr. Hughes, when they were exploited by a large staff of explorers. During the present exploration the coal was subjected to thorough and systematic search, borings and diggings being made in several promising localities in the vicinity of Therabwin. In every case, however, it was found to be economically useless. It occurs only as thin lenticular strings or pockets seldom more than 2 or 3 inches in thickness, largely mixed up with nodular white quartz, and containing a considerable percentage of ash. Often it scarcely deserves the name of coal, the shaly element predominates to such an extent. From an examination of the exposed outcrops of it, and from the results of the trial borings and diggings, I can say with some confidence that no workable coal is to be expected in the Moulmien group, at least in the Tenasserim division. This is a curious result considering that it is of carboniferous age, and the workable coal in Europe is mostly of that age.

The carboniferous coal worthless.

The workable coal is limited to the Tendau-Kamapying group, which is probably of tertiary age. The group covers an area of thirty square miles in the Tenasserim Valley. Within this area the coal has been met with only on the western side of the Tenasserim river. It has never been found on the eastern side: and there are considerations which make its occurrence there very unlikely.

The younger coal alone workable.

Occurs on the western side of the Tenasserim river.

On the western side of the Tenasserim river the coal was experimentally worked in 1843 for a year or so at a place called Chá Mitwe (Burmese for coal) in the village of Tendau. The old workings are situated at a distance of a little over three quarters of a mile from the Great Tenasserim river by the side of a small stream which, formerly known as Thatay-Chhaung, changed its name to Chá Mitwe since the working of the coal on its banks.

At Chá Mitwe (Tendau).

The coal had been extracted by open adits sunk on its dip for a distance of a few yards along this stream; shafts also had been sunk along the strike for a distance of a few hundred yards north and south of the stream. One of these (at a distance of 250 feet south of the point where adits had been sunk) struck coal at a depth of about 65 feet, but none of it was raised, the works having been abandoned shortly after the sinking of the shafts.

Old working.

Thickness of the coal in the Chá Mitwe stream.

The coal in the Chá Mitwe stream has a total thickness of 7 feet 2 inches including three partings of shales, and of 6 feet 8 inches excluding these.

The coal traced thence southwards.

The Tendau-Kamapying strata at the deserted workings have an inclination of about 30° E.N.E. Southward they are mostly concealed by alluvium as far as the Yángse Chhaung, in which there are good exposures, but presenting no indications of the existence of coal, so that it must have died out in the intervening ground. In this ground several boring sites were selected along strike-line calculated from the direction of dip in the Chá Mitwe stream. One of the borings at a distance of a quarter of a mile south of this stream gave the following section:—

	Feet.
Alluvium	28
Brownish shale	17
Black shale	2
Coal	8
Shale	7

The coal in this section very likely includes thin partings of shale, so that its thickness is approximately the same as at the deserted workings by the Chá Mitwe stream. The coal must continue for a short distance further south, but it dies out somewhere north of the Yángse Chhaung, for in that stream no indication of it was observed by Mr. Datta.

Traced northward.

Less than a mile and a quarter north of the Chá Mitwe stream there is a small stream covered by impenetrable jungle and specially infested by leeches, which is known as Bochypo-chhaung. It was carefully explored by Mr. Datta, but not a trace of the Tendau-Kamapying rock was visible, being hidden by alluvial deposits. A boring was tried at a site chosen on the strike, which, as seen by the Tenasserim close by is N. 20° W.—S 20° E. The rod after passing through the alluvium got down to conglomerates, progress through which was extremely slow. The boring had ultimately to be given up and another site was selected. Here, however, after the rod had gone down to nearly 70 feet without meeting coal or the shale accompanying it a bolt fell into the hole, which seriously obstructed progress; and this boring too was in the end abandoned.

The Heinlat, Kamapying.

North of the Bochypo-chhaung there is no indication of coal or of the shales with which it is associated until we reach the Heinlat stream, which is situated in the village of Kamapying. About a mile (measured in a straight line) from the junction of that stream with the Tenasserim river there is an outcrop of brownish shales resembling those in association with which coal is found elsewhere in the Tendau-Kamapying area. The shales, however, are only some 3 feet or so in thickness and rest upon massive-bedded arenaceous clay rocks without a trace of coal. Proceeding a couple of miles along the strike north-westward, there occurs in the same stream at a distance of three quarters of a mile to the west of the Tenasserim river a splendid seam of coal which at one point is no less than 23 feet in thickness. The coal was traced by close diggings and borings for a distance of about one hundred yards.

The following section was revealed at boring No. i:—

	Feet.	Inches.
Alluvium	2	0
Hard blackish shale	2	6
Coal (with very thin partings of shale)	28	6
Hard grey shale	2	6

About 84 feet south of this along the strike, a pit (ii) gave the following section:—

	Feet.	Inches.
Dark grey and blackish shale	3	0
Black shales with thin coal	2	6
Coal	18	0
Grey shale	7	0

Twenty-nine feet S. 5° E. from the last along the strike, a pit and boring (iii) disclosed the following section:—

	Feet.	Inches.
Decomposed brownish shale	1	6
Coal mostly shaly	2	6
Black carbonaceous shale	1	5
Coal	4	0
Black carbonaceous shale	0	9
Coal	0	9
Shaly Coal	3	0
Black shale	9	4
Shaly Coal	6	6
Yellowish brown shale	3	6

Thirty-three feet S. 5° E. from the last along the strike, the following section was obtained in pit (iv):—

	Feet.	Inches.
Decomposed shales	2	0
Alternations of brownish grey and black shales	5	4
Coal	0	9
Greyish black shales	3	3
" hard shales	2	2

Further south, some pits and borings were sunk, none of which disclosed any coal.

North of boring (i), some pits and borings were undertaken, in most of which the difficulty of passing through the sandy alluvium within the time and means at our disposal, and, in the case of pits, also of baling out water which appeared at only 3 to 8 feet under the surface, was found nearly insuperable. The two following, however, successfully reached down to coal. One boring at a distance of 130 feet N. 10° W. of boring (i) gave the following result:—

	Feet.	Inches.
Alluvium	9	0
Dark coloured shales	1	0
Hard black shales	4	0
Black shale with thin coal	0	6
Coal		

One pit 25 feet from the last, across the strike, exposed the following section:—

	Feet.
Reddish loam	12
Sand and gravel	4
Coal	2

(bottom not reached).

From these two sections and boring (i), it would appear that the coal here is at least 13 feet in thickness.

About three quarters of a mile further north on the Htiphanko, the following section was exposed by digging during the season 1891-92[1]:—

	Feet.	Inches
Coal	0	10
Shale	2	0
Coal	2	3
Shale	3	0
Coal	4	6

2 Quantity of the Coal.

At Kamapying.

From the sections given above it is evident that the coal on the Heinlat thins out and ultimately disappears rather suddenly in the southern direction. There may be some faulting between the pits (iii) and (iv). But even if there were, the impoverishment of the seam in the southern direction is plainly shown by (iii), in which within a distance of 30 feet the 18-feet bed of pure coal has already suffered marked deterioration. The coal may reappear, but from what is seen on the Heinlat close to its junction with the Tenasserim, it may be confidently asserted that it will not be of any thickness.

Northwards there is reason to believe that the coal continues, though with diminishing thickness, as far as the Htiphanko.

We shall be on the safe side if we assume the longitudinal extent of the coal at Kamapying to be only three quarters of a mile, which is very nearly the distance between the coal on the Heinlat and that on the Htiphanko. The dip in the Heinlat is 40°. But this is exceptionally high, and I think we shall be quite within the mark if we take 35° to be the average dip.

The workable depth to which the coal could be worked in such a part may be taken to be 300 feet. For such a depth the horizontal extension of the coal in the direction of the dip would be some 400 feet.

The average thickness of the workable coal, between the Heinlat and the Htiphanko, may be confidently taken to be 15 feet.

With these data, the total amount of coal at Kamapying would be found to be about 890,000 tons, taking 100 cubic feet of coal to be equivalent to only three tons.

As there is some doubt about the extension of the coal in the direction of dip to any long distance, it would probably be safer to assume it to extend for only

[1] Report on the Prospecting Operations, Mergui District, season 1891-92, p. 2, "Records, Geological Survey of India," Vol. XXVI, Part 1.

about 300 feet to the eastward, within which limit the coal could be worked at a vertical depth not exceeding 200 feet. On this assumption the total amount of available coal at Kamapying would be about 600,000 tons.

At Tendau.

At Tendau, the coal probably extends along the strike for about a mile and a half. Taking its mean thickness to be only 4 feet, the dip 30°, and the maximum vertical depth to which it could be worked 300 feet, the total amount of coal is found to be about 554,083 tons. If, on considerations stated in the preceding paragraph, the vertical depth be reduced to 200 feet, which would assume a horizontal extension of the coal in the direction of dip of about 340 feet, there would be about 380,000 tons.

5. Quality.

Assays.

The coal by the Heinlat stream is the best, the analysis of an average sample in the Survey Laboratory giving the following result:—

Moisture	16·40
Volatile matter	35·08
Fixed carbon	44·24
Ash	4·28

The coal cakes, though not strongly, and the ash is light buff.

The following is the result of analysis of a sample of coal from the Htiphanko stream explored during the season 1891-92:—

Moisture	11·34
Volatile matter	36·40
Fixed carbon	43·27
Ash	8·99

Sinters slightly, ash reddish brown.

Compared with Indian coal.

In the following table the coal is compared with some of the best known Indian coals:—

	Fixed carbon.	Moisture.	Volatile matter.	Ash.
Karharbari (average)[1]	63·66	...	24·01	12·33
Raniganj (good specimen)	51·80	...	37·50	10·70
Upper Assam[2] (Makum)	60·00	...	36·2	3·8
Heinlat (Kamapying)	44·24	16·40	35·08	4·28

As regards the percentage of ash the Heinlat coal compares very favourably with that of Makum, and is far superior to that of Raniganj and Karharbari. It contains, however, less carbon. It is a splendid steam coal, and, as it cakes, it would be well suited for smelting purposes also.

[1] Manual of the Geology of India, Vol. III, page 80.

[2] Manual of the Geology of India, Vol. III, page 103.

Pyrites in the Tendau coal.

The Htiphanko coal does not cake; and it, as well as the Tendau coal, especially the latter, contains iron pyrites which is supposed to render it liable to spontaneous combustion. The experimental working of the Tendau coal, fifty years ago, was given up chiefly on account of the presence of this objectionable element. The Heinlat coal, however, was found to contain very little of the pyrites.

Heinlat coal the best.

As regards thickness and quality, the Heinlat coal is by far the best in the whole coal-field. How far it maintains its thickness and quality in the direction of the Htiphanko it is difficult to say. On the Htiphanko it is found in an attenuated and somewhat deteriorated condition. It may, however, be safely asserted that half the estimated available coal[1] at Kamapying is of the Heinlat type.

The coal comes out in good blocks. A few tons of it were extracted from the Heinlat bed last season and tried in the launch *Ataran*. The engine-driver preferred it to any other coal he had used before. For steaming purposes it is above the average of Indian coals.

4. *Mining Expenses.*

High dip but no crushing.

The rather high dip of the coal is a somewhat objectionable feature about it and would make its extraction more expensive than in Bengal, where the coal has a very easy dip. The strata, however, are nowhere crushed or contorted. The shales above the coal will afford a firm roof, so that there might be no necessity for timbering.

Labour.

Labour would have to be imported from India. Our Indian coolies were paid R10 per month. For a permanency the rate would be lower. Besides, the agricultural possibilities of the area, which is at present greatly under-populated, are great; and those members of the miners' families who are not engaged in mining would find agriculture a very profitable pursuit. A colony of Indian miners from West Bengal would change the face of the country; and I have no doubt the district authorities will offer advantageous terms for their settlement.

Maximum outlay.

Taking into consideration the two unfavourable circumstances about the mining of the Tendau-Kamapying coal, *viz.*, high dip and high cost of labour, the following estimate[2] made by Mr. Hughes last year of the probable charges for one ton of coal at the pit on an output of 10,000 tons a year may be accepted as a maximum outlay:—

	R	a.
Labour	2	8
Stores	1	0
Establishment and supervision	1	0
Haulage and contingencies	1	0
Royalty	0	4
	5	12

[1] That is, about 300,000 tons according to the lower estimate.

[2] Report on the Prospecting Operations, season 1891-92, page 3. "Records Geological Survey of India," Vol. XXVI, Part 1.

Dr. Oldham also estimated the cost of the coal at the pit's mouth at about R5 per ton.

5. *Transit.*

(*a*) Water-carriage.

Carriage from the pits to the river.

The coal at Tendau as well as at Kamapying is situated about three quarters of a mile from the Great Tenasserim river; and the country between being tolerably level, a cart-road, or preferably tramway, could easily be constructed.

At Kamapying there are some bad rapids below which it would be advisable to take the coal if it has to be carried by water. The distance is only about two miles, over pretty level ground.

Bamboo rafts.

When the Tendau coal was experimentally worked in 1843, it was sent down to Mergui in bamboo rafts. Bamboo being plentiful in the area, the plan commends itself as economical, as the bamboos, after the rafts had been disburdened of their coal, would sell at a pretty high price at Mergui.

Objections to their use in systematic working.

However, though rafts might do for experimental working for a season or so, they would be quite unsuited for systematic working. In the first place, the gain in expense, which accrues from their use, is to a large extent counterbalanced by the loss in time. The coal I extracted at Kamapying was sent down the river by rafts as far as Banlaw, a distance of about 36 miles. They took nearly five days to reach that place, whereas boats would scarcely take two. Secondly, the coal would be partially soaked in salt water in its passage below Teraphon. Thirdly, though bamboos are plentiful, they would not meet the demand caused by a systematic working of the coal. Fourthly, even if they did meet the demand, the market at Mergui being glutted, their selling price would utimately become almost nominal.

Barges preferred.

If the coal be worked, and if it be conveyed by water, the best plan would be to have shallow-draught barges which could be towed down from Banlaw throughout the year, and from Therabwin during the greater part of it. As there is an abundance of good wood in the forests of the Tenasserim valley, the construction of boats would be a matter of no great expense.

(*b*) Land-carriage.

As the course of the Tenasserim between the coal-field and the port of Mergui is a most circuitous one, and as the river nearly as far down as Banlaw is full of shallows and rapids, offering serious obstructions to navigation, the idea of a railway has been broached. One of the objects of my exploration was to indicate the direction which such a railway would most advantageously take.

Only one track from the coal-field.

There is a track in the southern portion of the coal-field which leads from Chá Mitwe (Tendau) to Therabwin, crossing a spur at a place where it has a height of about 1,350 feet above the level of the surrounding country. There is no other track in the coal area. Even going from one village to another, one must go by water.

Track from Therabwin to Htombyo.

There are two fair weather tracks from Therabwin which are resorted to especially by cattle-dealers from Mergui and Tavoy. The best known of these is the one to Htombyo. It crosses the main hill range west of Therabwin at a point not more than 600 feet above the sea-level. The length of the track from Therabwin to Htombyo (in a straight line) is about 18 miles. The ground it traverses is comparatively easy. But the Kamapying coal would have to be brought down to Therabwin. The distance between the two places is not great, being only about 12 miles, but two hills would have to be crossed, one at a height of some 1,300 feet above the level of the adjacent country. The total length of the railway from Kamapying to Htombyo would be about 30 miles. But large sea going vessels cannot come up to Htombyo; so, the coal would have to be carried thence to Mergui in cargo boats or shallow draught steamers to be shipped to Penang or Rangoon, there being hardly any local demand.

Objections to it.

Track from Therabwin to Tanyet.

The same objection on the score of transhipment which always adds to the cost of transit holds in the case of the track from Therabwin to Tanyet, which has the additional disadvantages of being a little longer and of crossing a difficult mountainous country.

Track from Powat to Kyuh Phya.

North of the coal-field there is a track from Powat (8 miles north of Kamapying) to Kyuk Phya, a port accessible to large sea-going vessels. But the country between Kamapying and Powat is difficult, and for the purpose of carrying the coal the track will probably be found to be useless.

Suggested line.

If it be found advisable to have a railway at all, I would suggest a direct one from Kampaying to Kyukphya. The nature of the intervening country is not known at present, except that it is a trackless, unbroken jungle. But I do not expect it will be a very difficult one. The distance between Kamapying and Kyukphya is about the same as that between Kamapying and Htombyo. But Kyukphya being by the sea-side and having a good harbour, the suggested route, besides being shorter by the distance between Htombyo and Mergui, would save one transhipment.

Cost of transit.

It is difficult to estimate the cost of transit. If the coal be carried by water, as, in case of its being worked, it will very likely have to be for some time at least, the carriage from the pits at Kamapying to the river side below the rapids would be very little if a short tramway be constructed. Thence to Mergui if there be a service of specially constructed shallow draught cargo boats towed by launches from Therabwin or Banlaw, the cost of transit would not, I think, exceed R2 per ton.

6. Other mineral resources.

(*a*) Iron.

Lateritic ores in the valley.

In the course of the coal exploration, attention was also directed to the other mineral resources of the valley besides coal. Lateritic iron ores are widely distributed in the valley; but they are superficial deposits and do not, as a rule, appear to be rich.

One sample analysed in the Survey Laboratory was found to contain 36·06 per cent. of iron. Another sample from Therabwin contains 50·49 per cent. of iron.

But these samples are of exceptionally good quality. The general run of the ores is far inferior to them, and I do not think their quantity or quality is such as to afford scope for an industry on a commercial scale.

At Maha Champa.

Close to the mouth of the Tenasserim, however, 6 miles to the west of Mergui, at a place called Maha Champa (at the southern extremity of the Kola Gyun Island) I came upon extensive deposits of iron ore. It, too, is of a lateritic character, being the result of the alteration of argillaceous schists belonging to a group of rocks older than the "Moulmein" to which the name of "Mergui" has been applied by Dr. Oldham ("Geological Papers on Burma," p. 377). The ores cover at least one square mile of ground; and though from its nature it cannot go down more than a few feet below the surface, what there is exposed appeared to me practically inexhaustible. The quality is not very good. But the quantity would make up for this deficiency. A mixture of several samples (good and bad) was found to contain, by assay in the Survey Laboratory, 36·8 per cent. of iron.* An assay of a rather picked sample showed 37·58 per cent.

Field for an iron industry.

The boats which would carry down coal to Mergui could take up the iron ore to the coal-field, so that its carriage would but entail little additional expense. If the boats did not carry the ore, they would mostly have to go back empty to the coal-field, which would be very uneconomical. Should the coal be worked, I would advise a fair trial of the Maha Champa iron ores. The Heinlat coal has been found to cake; and there is splendid flux at Therabwin, as will be shewn presently. At present the demand for coal in the Tenasserim division is confined to a few steamers plying along the coast. They have been hitherto mostly using wood. But a tax has been recently imposed upon fire-wood which will have the effect of raising its price probably so high as to make the substitution of fair-priced coal desirable. But even then, the local demand will never be sufficient to support a properly worked mine. It would mostly have to be shipped off to Rangoon or Penang. In the event of iron works being started on the coal-field or close to it they would absorb a good quantity of the coal, and thus reduce the dependence on the distant markets of Penang and Rangoon.

I must say, however, that the local demand for iron is surprisingly small. Almost the only articles which the people want it for are knives and axes. They generally do without ploughs, and when they have any, iron does not enter into any part of their construction. They seldom use any cooking utensils made of iron. Wood is so abundant that it will continue to be used for beams, railings, etc., for a long time to come. There is not a single blacksmith in the district outside the town of Mergui. But the requirements of the different districts constituting the Tenasserim division will be considerable, and what is not taken up by them would probably be more profitably exported to Rangoon and Penang than coal.

* The iron ores in the neighbourhood of Barakar, which are used in the works at that place contain from 24·24 to 49·63 per cent. of iron, so that the average percentage is about the same as that contained in the Maha Champa ores. (See Manual of the Geology of India, Vol. III, page 370.)

(*b*) Limestone.

The limestone ridges in the vicinity of Therabwin would supply excellent flux. A sample of the limestone has been analysed in the Survey Laboratory with the following result:—

Insoluble in dilute H. Cl.	13·40
Oxide of iron and alumina	0·61
Carbonate of lime	85·85
Carbonate of magnesia (by difference)	0·14
	100·00

If iron works be started, I think Therabwin would be a good site for them. It is quite close to the coal-field; shallow-draught launches can come up to it throughout the year; and it has a large extent of flat ground suitable for a settlement.

(*c*) Tin.

Tin was formerly worked for at the following places in the valley of the Great Tenasserim:—

(1) Tendau (close to the coal-field) at the head-waters of a stream of the same name.
(2) Tagu, near the source of a stream of the same name.
(3) Myengyee, about 6 miles N. N.-W. of Tenasserim.
(4) Marton—There are numerous old pits along the foot of a range of granitic hills north-east of the village.
(5) Zoe, about 8 miles N. N.-W. of Marton.

There are also several localities in the Little Tenasserim valley where tin was worked of old. At present tin workings are confined to a place called Thebawlik, about 18 miles to the west of Tenasserim. For information regarding these and several of the deserted workings in the Great Tenasserim valley I would refer to the reports of the prospecting operations under Mr. Hughes published by the Government of Burma.

(*d*) Gold.

It is still washed for on a very small scale in the Tenasserim river at the old town of Tenasserim. I mention its occurrence more with a view to make the list of the mineral resources of the Tenasserim valley complete than to raise hopes of remunerative exploitation.

7. *Summary.*

The results of the coal-exploration embodied in the present report may be summarized as follows:—

(1) There is, in the Mergui district, coal of two distinct ages, carboniferous and tertiary.
(2) The carboniferous coal is far more widely distributed than the tertiary, but is economically worthless.
(3) The tertiary coal occurs at two localities—Chá Mitwe (Tendau) and Kamapying, both situated on the right, or western, bank of the river

Tenasserim. There is hardly any chance of the coal being found on the eastern side of the river.

(4) The available quantity of coal at Kamapying is *at least* 600,000 tons, and at Chá Mitwe *at least* 380,000 tons.*

(5) For steaming purposes the coal is far above the average of Indian coals.

(6) The coal on the Heinlat at Kamapying is the most promising in the whole field. It is very thick, cakes though not strongly, and is almost free from iron pyrites, the presence of which in some abundance in the Tendau and the Htiphanko coal detracts from its value. There are at least 300,000 tons of the Heinlat type of coal at Kamapying.

(7) Having regard to the high dip of the coal and the difficulty of getting labour locally, the expense of working the coal on a fairly commercial scale would amount to about R5 per ton.

(8) The cost of transit to Mergui would amount to about R2 per ton, if the coal be carried in specially constructed shallow-draught barges towed by stern-wheel launches from Therabwin or Banlaw.

(9) If a railway be constructed the best alignment would, I am inclined to think, be from Kamapying, where we have the best coal, to the port of Kyukphya, which is accessible to large sea-going vessels. The distance is about 28 miles.

(10) The presence of extensive deposits of iron ore at the southern extremity of the Kola Gyun Island, 6 miles west of Mergui, and the occurrence of excellent limestone at Therabwin are circumstances highly favourable to the working of the coal, as an iron-industry would locally absorb a good quantity of it.

On a Magnetite *from the* Madras Presidency containing Manganese *and* Alumina, *by* T. H HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India.*

Amongst a number of manganese ores recently received from the Kodúr mines, south of Chipparupale, Vizagapatam district, Madras Presidency, a specimen labelled "braunite" attracted my attention from its resemblance to magnetite. I found it to be strongly magnetic, exhibiting distinct polarity; and it had also the lustre, hardness and colour of magnetite, but gave a distinctly reddish brown streak. The specimen was composed of a mass of granules, each about ¼ inch across, and limited by faces which were apparently the result of mutual interference during the growth of adjacent crystals.

* These figures preclude the possibility of mining in the Tendau-Kamapying field on such a large scale as that on which some of the Indian mines are worked. The annual output of several of these exceeds forty thousand tons.

A number of crystals gave an average *specific gravity* of 5·045.

Chemical analysis gave the following results:—

Moisture lost below 105° C.	0·14	
Residue insoluble in hydrochloric acid	0·11	
Water lost by ignition	2·18	
Alumina (Al_2O_3)	2·52	
Ferrous oxide (FeO)	26·84	Fe_3O_4, 91·62
Ferric oxide (Fe_2O_3)	64·78	
Manganese oxide (Mn_3O_4)	3·00	
	99·57	

Separate determinations of the iron and manganese gave 66·74 per cent. Fe (equal to 92·16 Fe_3O_4); 2·183 and 2·144 per cent. Mn (equal to 3·03 and 2·98 Mn_3O_4 respectively).

Neglecting the hygroscopic moisture and insoluble matter (both very small), and calculating to 100, we obtain:—

H_2O	2·19
FeO	27·03
MnO	0·94
Al_2O_3	2·54
Fe_3O_4	65·22
Mn_3O_4	2·08
	100·00

Calculating the atomic ratios of these we have—

	$R^{ii}O$	$R_2^{vi}O_3$
Fe	·3754	·4077
Mn	·0132	·0132
Al	...	·0247
H	·1216	...
	·5102	·4456

The protoxide group thus appears in excess of the sesquioxides, evidently due to calculating the water as a protoxide. The water, therefore, must be regarded, in part at least, as a hydrate of one or more of the bases.

On comparing these results with previously recorded analyses of magnetites, we find that manganese has been found before replacing the iron, either with or without magnesia, but I know of no case in which at the same time alumina replaces the sesquioxide. The nearest approach to the Madras specimen seems to be a mangan-magnetite from Vester Silfberg, described by Mats Weibull. Its specific gravity (5·064) agrees closely with that of the Madras mineral, and, as the author remarks, it is slightly lighter than ordinary magnetite. A chemical analysis by Rudelius gave—

FeO	26·93
MnO	3·80
Fe_2O_3	69·32
	100·05[1]

A variety of magnetite from New Zealand, analysed by Mr. F. J. Cairns, under the direction of Professor A. H. Chester, in 1888, gave 4·98 per cent MgO and 4·82 per cent Mn_3O_4[2]. The Vizagapatam specimen is thus a new variety.

[1] *Min. und. petr. Mittheil.*, vol. VII (1886), pp. 109 and 110.

[2] *Min. Mag.*, vol. VIII (1889), pp. 125 and 126.

On Hislopite (Haughton); *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Geological Survey of India*, (with a plate).

I.—HISTORY AND CHEMICAL COMPOSITION.

In the year 1858, Prof. Haughton proposed the name *Hislopite* for "a remarkable combination of calc-spar and glauconite" found by the Rev. S. Hislop at Nagpur in the Central Provinces.[1] The specimen described presented the crystalline form of calc-spar; was of a brilliant grass-green colour, and effervesced briskly with weak hydrochloric acid, which dissolved its calcareous portion, leaving a beautiful, green, siliceous skeleton described by the author as "glauconite." The original specimen, according to Professor Haughton's analysis, was composed of—

Green siliceous skeleton (glauconite) .	16·63
Alumina	0·73
Carbonate of lime	80·79
Carbonate of magnesia	trace.
	98·15

From the description it appears that the substance was found associated with zeolites and other secondary minerals infilling crevices and amygdaloidal cavities in the Deccan lavas, which are known for the variety and beauty of the large crystals of hydrous silicates which they have yielded.

There seems little doubt, also, that "hislopite" is the substance mentioned by Lieutenant-Colonel Sykes in his paper "On a portion of the Dukhun, East Indies," communicated to the Geological Society of London in 1833. Col. Sykes found masses measuring 2 feet across, of a green colour, exhibiting the form of calc-spar *but of lower specific gravity*[2] (*vide infra*, specific gravity, p. 168).

A specimen of calcite recently sent by the Hyderabad (Deccan) Company for determination presented somewhat similar characters to those of hislopite described by Prof. Haughton. Well-developed cleavage rhombs of calcite showed included patches of green material, similar to the green earth which is so common in the amygdules of the Deccan lavas, and which has generally been referred to as *glauconite*. Sections examined under the microscope show a groundmass of calcite, with its characteristic cleavage and occasional *Gleitflächen*, including botryoidal and irregular masses of green earth (glauconite in part); and a colourless mineral, polarising with low colours of the first order, and exhibiting extinctions inclined to all the section-outlines. These, which frequently include portions of the green earth, proved, on separation by means of heavy liquids, to be *heulandite* (see plate).

[1] *Journ., Roy., Dub. Soc.*, vol. II (1858-59), pp. 176 and 177; *Phil. Mag.*, 4th ser., vol. XVII (1859), pp. 16-18.

[2] *Trans. Geol. Soc.*, vol. IV, p. 425.

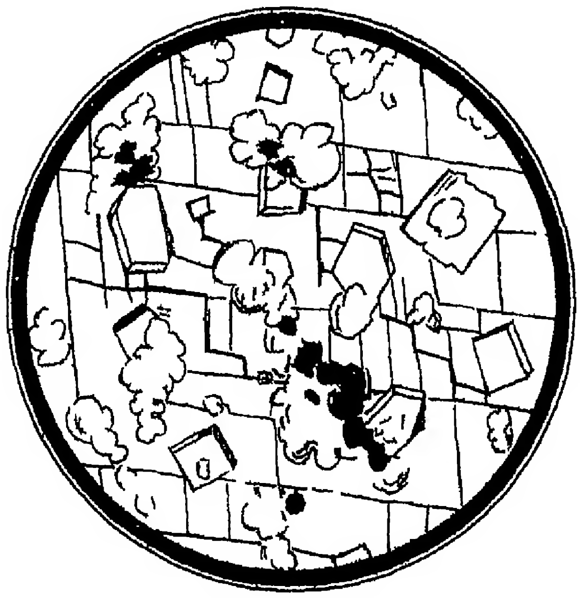

Fig 1

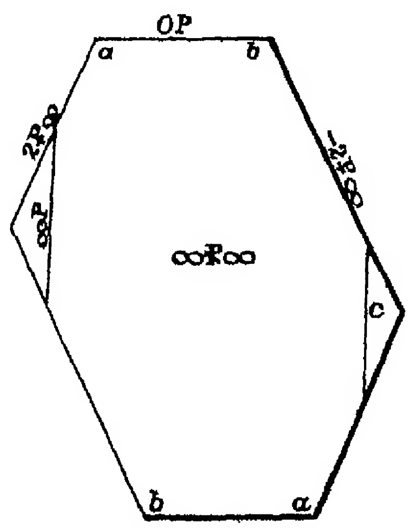

Fig 2

Two fragments were selected for determination of the carbonic acid. One piece yielded 31·47 per cent. (CO_2) as an average of two closely agreeing results. The second fragment, kindly analysed for me by Mr. J. Cleghorn, of the Public Works Department, gave 30·49 per cent. The average of these two results (30·98) indicates the presence of 70·41 per cent. of lime carbonate, the remainder (29·59 per cent.) being composed of heulandite, green earth and moisture.

The complete analysis of the substance is as follows :—

Specific gravity of the fragment analysed, 2·546[1].

Chemical composition.

Moisture	4·031
Residue insoluble in acetic acid	23·476
Fe_2O_3 and Al_2O_3	0·247
CaO	40·483
CO_2	30·980
	99·217

The iron, alumina and a small portion of the lime are derived from the green earth and heulandite, both of which are slightly attacked even by cold acetic acid. By this decomposition there is a small loss, due principally to the combined water in these hydrated minerals, and which cannot be accounted for by this method of analysis. Hence the total is below 100. A low total, probably from the same cause, may be noted in Prof. Haughton's analysis.

The above results show a much larger proportion of the included minerals than that indicated by Prof. Haughton's analysis. But such variations need not be surprising for three reasons :—(1) The green earth is partially, and the heulandite wholly, decomposable by hydrochloric acid, the solvent which Prof. Haughton used to separate the carbonate of lime from the green siliceous skeleton. Hence the insoluble residue would be less than the total mineral included in the calcite. Even in acetic acid these included minerals are partially soluble. (2) The proportion of heulandite to green earth is variable. (3) The foreign substances are only mechanically included in the calcite, and consequently there is no necessary proportion between the minerals included and the host. This statement is verified by the results recorded below.

Prof. Haughton in a later paper gives the following result of his analysis of

[1] With the chemical analysis of *mixtures* of minerals (as all rocks are) in which the proportion of constituents is variable, it is very important to determine the specific gravity of the *actual fragment analysed*, whatever be its size. In this way a quantitative mineral composition can often be stated with considerable accuracy (*vide Rec., Geol. Sur. Ind.*, vol. xxiv, (1891), pp. 232 and 236). The same remark applies equally to minerals, in which (the spinels for example) isomorphous compounds replace one another to varying degrees. In offering this suggestion I do not imply that the advantage of this proceeding is overlooked by other workers but whilst in many published analyses other details (some none, the less important) are carefully recorded, the discrepancy between the specific gravity and chemical analysis, which is often so evident, shows that this precaution is still frequently overlooked, with the result that the scientific value of the result is greatly depreciated.

"calc-spar, clouded-like plasma, with pale greenish streaks of a siliceous mineral":—

Carbonate of lime	97·19
Green siliceous mineral	2·81
	100·00

He remarks that "the quantity of colouring mineral was too small for examination, and its percentage much less than that of the Glauconite, which gives its rich green colour to Hislopite [1]."

It would seem from this last remark, and from the fact that on the same page the author refers to the *new minerals* hislopite and hunterite, that he regards the proportion of green siliceous mineral as important, and places specific value on the term *hislopite*. With this in view I examined a specimen of green calc-spar in the Geological Museum, Calcutta, labelled "Hislopite, Nagpur." The analysis showed—

Carbonate of lime	95·385
Moisture, inclusions, etc.	4·615
	100·000

Specific gravity of fragment analysed . . . . . . 2·659

There is thus a great variation in the quantity of material included in the calcite; sometimes the inclusions are greater in quantity and sometimes less than that found in the original specimen of hislopite.

II.—SPECIFIC GRAVITY.

The variation thus found in different specimens is evident to the naked eye in the specimen of green calcite sent by the Deccan Company. But a comparison of the specific gravities of different fragments demonstrates this fact more conclusively, and shows how the inclusions, when occurring in large quantities, give the specimen a lower specific gravity, as was noticed by Colonel Sykes in 1833 (*vide supra*, p. 166). This, of course, is due to the fact that both heulandite and glauconite are lower in specific gravity than calcite:—

SPECIMEN.	Sp. gr.	Carbonate of lime.	Moisture and minerals included (by difference).	Insoluble residue (by experiment).
A. Specimen sent by Hyderabad (Deccan) Company.	2·546	70·41	29·59	23·47[2]
B. Hislopite, original specimen analysed by Haughton.	2·645	80·79	19·21	16·63[3]
C. Specimen labelled "Hislopite, Nagpur," in Geological Museum, Calcutta.	2·659	95·38	4·62	2·340[2]
D. Clear Iceland spar, small fragment cut from A.	2·711	99·12	0·88	...

[1] *Phil. Mag.*, 4th Ser., vol. XXIII (1862), p. 50.

[2] Insoluble in acetic acid.

[3] Insoluble in hydrochloric acid.

Specimen A varies so much in different parts that whilst, as shown, by D, it is in places made up of transparent Iceland spar, in other places the green earth occurs in such quantities that the presence of calcite is only manifested by using acid.

Of this specimen (A) in which the inclusions are well-defined, I have determined the specific gravity of the insoluble residue[1] and find it to be 2·42. Taking the specific gravity of calcite as 2·72, we have:—

Calcite . . .	2·72 × 70·41	=	191·6
Green earth and heulandite	2·42 × 23·47	=	56·8
Moisture (difference) .	1·00 × 6·12	=	6·1
	TOTAL .		254·5 = 100 × 2·545

This result agrees thus very closely with 2·546 (the specific gravity of A as determined by experiment) and in this particular case the very close approximation is doubtless accidental; but from analogy of many other examples I should expect agreement to the second decimal point.

III.—MINERALS INCLUDED.

To determine the nature of the included minerals, I dissolved a large fragment in acetic acid and treated the residue with a heavy liquid. The material was by this means divided into three portions:—

(1) The green botryoidal masses.
(2) Compound grains, or crystals of heulandite with *included* green earth.
(3) Clean heulandite crystals.

(1). *The green earth.*—The first portion had a specific gravity of 2·62, which is high for glauconite, but may be accounted for by the numerous apple-green, opaque portions, probably referable to *celadonite.* On account of the composite nature of the material, as shown by the microscope, a quantitative chemical analysis would be of little value. I found, however, that it gave off water on heating, fused before the blowpipe to a black magnetic glass, and was partly decomposable by hydrochloric acid, colouring the acid by the dissolved iron. The first treatment with acid changed the colour of the masses from a pistachio-green to an apple-green colour, which I attribute to celadonite.[2]

(2). *The compound grains.*—Were disregarded.

[1] By Smeeth's method (*Proc. Roy. Dublin Soc.*, Vol. VI (1888), p. 61). I have modified the method by using paraffin instead of vaseline, as the latter substance is of oily consistency in this climate.

[2] *Cf.* Heddle on Celadonite, *Trans. Roy. Soc. Ed.*, vol. XXIX (1879), p. 102. It may be remarked that the percentage of silica, 54·59, obtained by Prof. Haughton from the green siliceous residue of his hislopite agrees very closely with the average of the results given by Prof. Heddle for four specimens of celadonite (54·84); but I would place very little value upon this agreement, for the green earth which I have separated from the calcite is decidedly composite in character, and, unlike celadonite, a large proportion of it is decomposable by hydrochloric acid. Moreover, the heulandite, with which it is associated in the green calc-spar, is decomposable by hydrochloric acid, and would consequently contribute a variable but serious amount of silica to Prof. Haughton's insoluble residue ("Green siliceous skeleton").

(3). *The heulandite crystals.*—The third portion consisted of minute glistening plates, seldom measuring more than 0·25 mm. in any direction, and with a specific gravity of 2·21. Most of the crystals agree in form with those of heulandite given by Artini.[1] They are generally combinations of basal plane (OP), orthodomes ($2\bar{P}\infty$ and $-2\bar{P}\infty$), prism (∞P), and clinopinacoid ($\infty\bar{P}\infty$), (Fig. 2). As the clinopinacoids are in all cases well-developed, the crystals naturally lie on those faces, and so allow of an easy determination of the angles between the basal plane and dome faces by revolving the cross wires of the microscope. The angles obtained in a large number of examples agree very closely with those recorded for undoubted heulandite. They are—

$OP \wedge 2\bar{P}\infty$ . . .	116°.	(116° 20′, quoted by Dana).
$2\bar{P}\infty \wedge -2\bar{P}\infty$ . .	130°.	(129° 40′, " " ")
$OP \wedge -2\bar{P}\infty$ . . .	114°.	(114°, " " ")

The crystals between crossed nicols are generally seen to be zoned parallel to the dome faces and basal plane, extinction angles, therefore, show variations from 6° to 12° measured from the line of intersection of prism and clinopinacoid (parallel to vertical axis)[2]. Crystals turned up in viscous Canada balsam with their clinopinacoids perpendicular to the slide show straight extinction. In some cases, when lying on their clinopinacoids, they are seen between crossed nicols to be divided into four sectors, two of which extinguish at the usual angle, whilst the other two exhibit almost straight extinction. This, and the zoning, may be due to intergrowths or successive growths of heulandite with the dimorphous form, epistilbite, or with either of the closely related species mordenite, stilbite, and laumontite. Still, crystals showing undoubted heulandite characters prevail, and the results of Rinne, Hussak, Negri and Artini show some curious variations in the optical properties of this mineral obtained from different localities.

When heated before the blowpipe the crystals swell and fuse to a white enamel. On treatment with hydrochloric acid decomposition takes place rather slowly, the residue of silica retains the perfect outline of the original crystal, but is traversed by irregular cracks, and is isotropic between crossed nicols. If the action of the acid is not too prolonged, cores of undecomposed mineral are left, but showing apparently only irregular shapes.

There seems no reason why other zeolitic minerals of about the same specific gravity should not occur mixed with the heulandite crystals in subordinate proportions.

IV.—SUMMARY.

(1) The handsome crystals of green calcite from the Deccan "traps" contain inclusions which vary greatly in amount and sometimes exceed the host in quantity.

(2) The inclusions consist of—(*a*), a green earth of rather indefinite composition, but consisting in part of material closely resembling that which has been described as celadonite, and (*b*) crystals of heulandite.

(3) There is a variable, but no essential, connection between the proportion of calcite and the minerals which it includes, the specific gravity of any fragment

[1] *Vide* Dana: System of Mineralogy (1892), pp. 574 and 576.

[2] *Cf.* Levy and Lacroix, *Les Minéraux des Roches* (1888), *Heulandite non deformée*, p. 310.

being that of a mixture of the component minerals. Prof. Haughton has described as a "new mineral" (*vide Phil. Mag.*, vol. XXIII (1862), p. 50), a specimen of calcite containing 17·36 per cent. of glauconite, under the name *hislopite*. The name hislopite loses its specific value when the variation of the included so-called glauconite is proved to be so great as the foregoing results show; and still more so when it is found that glauconite is neither the only, nor, indeed, always the most abundant, inclusion in the calcite.

EXPLANATION OF PLATE.

Fig. 1. Section of calcite showing its rhombohedral cleavage with inclusions of botryoidal masses of green earth and clear crystals of heulandite. Inclusions of the green earth in the heulandite are very common. Magnified by 40 diameters.

Fig. 2. Crystal of heulandite lying on its clinopinacoid. Length of crystal between its basal planes 0·25 mm.

$$a = 0P \wedge 2\,\bar{P}\infty = 116^\circ$$
$$b = 0P \wedge -2\,\bar{P}\infty = 114^\circ$$
$$c = 2\,\bar{P}\infty \wedge -2\bar{P}\infty = 130^\circ$$

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 17.—ENDING 31ST OCTOBER 1893.

Director's Office, Calcutta, 31st October 1893.

The disposal of officers during the next field season (1893-94) has been arranged as follows:—

SCIENTIFIC.

Baluchistan and N. W. Frontier.

Mr. C. L. Griesbach, C. I. E., Superintendent.
Mr. F. H. Smith, Assistant Superintendent.
Babu Kishen Singh, Sub-Assistant.

Madras.

Mr. C. S. Middlemiss, Deputy Superintendent.
Dr. Warth, do. do.

Burma.

Dr. Fritz Nöetling, Palæontologist.

Rewa State.

Mr. P. N. Bose, Officiating Superintendent.

Central Provinces.

Mr. P. N. Datta, Assistant Superintendent.

Head-quarters and Tours.

The Director.
Mr. T. H. Holland, Assistant Superintendent.
Babu Hira Lal, Sub-Assistant.

ECONOMIC.

Sukkur Experimental Boring.

Mr. T. D. LaTouche, Officiating Superintendent.

Superintendents, Messrs. T. W. Hughes and R. D. Oldham are on sick leave and furlough; and within the last month Mr. Assistant Superintendent W. B Dallas Edwards has also been sent home on sick leave.

The Director was on tour in the Madras Presidency from the beginning of September to the middle of October, when oppoitunities admitted of a conference with the Government of Madras as to the disposal of a geological officer for further continued survey in the Presidency. It was arranged that Mr. Middlemiss will complete the mineral survey of the Salem District, the western portion of which still remains open to further exploration; and that the occurrence of corundum is to be made the immediate object of inquiry according as this mineral and its associated rocks are studied in the course of survey. In this connection it is also proposed, when the district is finished, to initiate a series of disuict Mineral Manuals by the issue of one on the Salem District.

Opportunity was taken to examine certain areas of the crystalline rocks, particularly at the Palaveram hill near Madras, in connection with recent petrological observations which had been made by Mr. T. H. Holland while on deputation at different times for the Imperial Institute inquiries into the iron resources of Southern India: and to which reference was made in his paper (Records XXV, pp. 141-45) on the *Iron Ores and Iron Industries of Salem*, and in the Tri-monthly Notes of the same volume. It may be remembered that, in the Annual Report of the Survey for last year, it was stated that :—

"Another noticeable feature amongst the rocks collected in the South of India is the wide prevalence of the mineral hypersthene, and, to a less extent, other members of the pyproxene group. This mineral occurs as a constituent of rocks varying in composition from hypersthene-microcline granite to norite and hypersthene-rock. The very wide area over which Mr. Holland's tour for the collection of specimens and information extended prevented his doing more than a superficial examination of these rocks, but I look upon them as a promising sequel to the petrological results obtained by M. Lacroix on the Salem and Ceylon specimens; and they promise to be only an earnest of what may be expected from a more detailed examination of this complex area. It seems likely that many of the rock-masses which have been provisionally mapped as metamorphic will be found, as Dr. Lawson has shown in the Rainy Lake Region of Canada, to be merely rolled-out laccolites and intrusive bosses—some with a well-defined parallelism of constituents, but passing by impeiceptible gradations into true granitic structures."

Since this was written, Mr. Holland has paid two more visits to Madras, the latter in company with the Director, to some of the rock 'massifs' referred to in the closing passages of the above extract, namely the Nilgiris, the Shevaroy Hills, and Palaveram, from the recorded observations in which and the suites of specimens collected, it now seems certain that these masses are really such laccolites and intrusive bosses of igneous rocks as he indicated. These discoveries necessarily involve considerable modification of the views of the earlier surveyors regarding their interpretation of the Nilgiri and Shevaroy rocks as belonging to a great series of very old gneissic or highly metamorphosed sedimentary deposits; although the rocks of the wide plains, stretching away from, and surrounding, those hill groups are still open to such a classification as being a decidedly more foliated and pseudo-bedded series, among which these newly-discovered granites were irrupted. The whole question of the history and constitution of the Madras crystallines is, however, as yet only advanced thus far, and it must wait the results of the further survey, which is now being gradually carried out.

List of assays and examinations made in the Laboratory, Geological Survey of India during the months of August, September and October 1893.

Substance.	For whom.	Result.
1. Specimen of quartz, with iron pyrites and visible gold.	Gillanders, Arbuthnot & Co., Calcutta.	Assayed for gold.
2. Specimens of quartz, from the ancient gold workings (discovered by R. Sewell, I.C.S., Collector of Bellary) near Yeutanbatti, Bellary.	Dr. H. Warth, Officiating Superintendent, Government Central Museum, Madras.	(I) White quartz. Quantity received, 34 lb. Contains no gold. (II) Blue quartz. Quantity received, 33 lb. Contains no gold.
Nodules from the lavender shales between Ratwahi and Jalar, Salt Range.	C. S. Middlemiss, Deputy Superintendent, Geological Survey of India.	= Barytes. sp. gr. 4·43.
A "small sample of stone" for determination.	Balmer Laurie & Co., 103, Clive Street, Calcutta.	= Iron pyrites.
A specimen of stone locally called "Hiranchi," found in the hills at Tehie Ghatia, Kawardha State.	A. S. Womack, I.C. S., Political Agent, Chhattisgarh Feudatories, Raipur, Central Provinces.	= Hematite.
A specimen of "certain stones," found at Manza Sagar, Government estate of Damin-i-Koh.	H. H. Heard, Sub-divisional Officer, Godda.	= Limonite.
A specimen from Badshahr, Persia; found by Mr. Ferrell; supposed to contain gold.	W. Coldstream, I.C.S, Deputy Commissioner, Simla.	= Mica schist; contains no gold; the shining particles being mica, stained with iron.

Notification by the Geological Survey of India during the months of August, September and October 1893, published in the "Gazette of India," *Part II.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Geological Survey Department.	1300, dated 31st August 1893.	P. N. Datta, Assistant Superintendent, Geological Survey.	Privilege	7th September 1893.	...	...

Anuual increments to graded officers sanctioned by the Government of India during August, September and October 1893.

Name of officer.	From	To	With effect from	No. and date of sanction.	REMARKS.
	R	R			
P. N. Datta, Assistant Superintendent, Geological Survey . .	470	500	1st July 1893.	Revenue and Agricultural Department No. $\frac{1880}{158}$, dated 3rd August 1893.	
C. L. Griesbach, Superintendent, Geological Survey. . . .	950	1,000	1st August 1893.	Do. No. $\frac{1927}{167}$, dated 7th August 1893.	
F. H. Smith, Assistant Superintendent, Geological Survey .	380	410	Do.	Do. No. $\frac{1929}{168}$, dated 7th August 1893.	
F. H. Holland, Assistant Superintendent, Geological Survey. .	410	440	1st September 1893.	Do. No. $\frac{2427}{194}$, dated 29th September 1893.	

Notifications by the Government of India during the months of August, September and October 1893, published in the "Gazette of India," *Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.*

Department.	No. of order and date.	Name of officer.	From	To	Nature of appointment, etc.	With effect from	REMARKS.
Revenue and Agricultural Department.	$\frac{1150}{60}$, Surveys, dated 30th August 1893.	P. N. Bose.	Deputy Superintendent.	Officiating Superintendent.	Acting, temporary.	18th July 1893.	

Postal and Telegraphic Addresses of Officers.

Name of officer.	Postal address.	Nearest Telegraph Office.
T. W H. Hughes	On furlough.	
C. L. Griesbach	Quetta	Quetta.
R. D. Oldham	On furlough.	
P. N. Bose	Rewa	Rewa.
T. H. D LaTouche	Sukkur	Sukkur.
C. S. Middlemiss	Madras	Madras.
W. B. D. Edwards	On furlough.	
P. N. Datta	Nagpur	Nagpur.
F. Noetling	Dandot	Dandot.
Hira Lal	Calcutta	Calcutta.
Kishen Singh	Quetta	Quetta.

DONATIONS TO THE MUSEUM.

FROM 1ST AUGUST TO 31ST OCTOBER 1893.

A large weathered specimen of limestone from "Madhupur, E. I. R." and another from Katni, Jubbulpore.

PRESENTED BY JAS. CLEGHORN, BALLYGANJ.

A large block of Steatite from Raiwala, Jeypore State, and smaller specimens from Kanheri village, Bhandara District, and from the marble rocks, Jubbulpore.

PRESENTED BY THE OFFICIATING REPORTER, ECONOMIC PRODUCTS TO THE GOVERNMENT OF INDIA.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1893.

Titles of Books. *Donors.*

ABEL, *Sir F. A.*—Mining accidents and their prevention. 8° New York, 1889.

BALL, *Dr. V.*—The volcanoes of Barren Island and Narcondam in the Bay of Bengal. 8° Pam., Hertford, 1893. THE AUTHOR.

BLOCHMANN, *Dr. Friedrich.*—Untersuchungen über den Bau der Brachiopoden. Text and Plates. 4° Jena, 1892.

BONNEY, *Prof. T. G.*—The Year-book of Science for 1892. 8° London, Paris and Melbourne, 1893.

BRONN'S Klassen und Ordnungen des Thier-Reichs. Band IV., lief. 44-45. 8° Leipzig, 1893.

FOREL, *F. A.*—Le Leman (The Lake of Geneva). Tome 1. 8° Lausanne, 1892.

HUGHES, *Herbert W.*—Text-book of Coal-mining. 8° London, 1892.

KAYSER, *E.*, and LAKE, *P.*—Text-book of Comparative Geology. 8° London, 1893.

KUNHARDT, WHEATON *B.*—The Art of Ore-dressing in Europe. 8° New York, 1889.

LUNGE, *George*, AND HURTER, *F.*—The Alkali-makers' Hand-book. 8° London, 1891.

MAR, *Alexander Del.*—A History of the precious metals from the earliest times to the present. 8° London, 1880.

PHILLIPS, *W. B.*, AND PROCHASKA, *E.*—Weddings' Basic Bessemer Process. 8° New York, 1891.

POMPECKJ, *Dr. J. F.*—Beiträge zu einer Revision der Ammoniten des Schwäbischen Jura. Lief. 1. 8° Stuttgart, 1893.

ROBERTS, *R. D.*—The Earth's History. 8° London, 1893.

SUESS, *Ed.*—Die Zukunft des Silbers. 8° Wien and Leipzig, 1892.

DR. WILL. KING.

TRYON, *Geo. W.*—Manual of Conchology, Vol. XII, part 55, and 2nd series, Vol. VI, part 31. 8° Philadelphia, 1893.

WAHNSCHAFFE, *Dr. Felix.*—Die Ursachen der Oberflächengestaltung des Norddeutschen Flachlandes. 8° Stuttgart, 1893.

WATT, *Dr. George.*—Dictionary of the Economic Products of India, Vol. VI, parts 3-4. 8° Calcutta, 1893. GOVERNMENT OF INDIA.

WILSON, *Eugene B.*—Mine ventilation, practical and theoretical. 8° New York, 1891.

PERIODICALS, SERIALS, ETC.

Titles of Books. *Donors.*

American Geologist. Vol. XI, Nos. 1-3. 8° Minneapolis, 1893.

American Journal of Science. Vol. XLVI, Nos. 271-272, 8° New Haven, 1893.

American Naturalist. Vol. XXVII, Nos. 318-319. 8° Philadelphia, 1893.

Annalen der Physik und Chemie. Neue Folge, Band XLIX, heft 3-4; and L., heft 1. 8° Leipzig, 1893.

Annals and Magazine of Natural History. Vol. XII, Nos. 67-69. 8° London, 1893.

Athenæum. Nos. 3425-3437. 4° London, 1893.

Beiblatter zu den Annalen der Physik und Chemie. Band XVII, Nos. 5-7. 8° Leipzig, 1893.

Chemical News. Vol. LXVII, No. 1751 to LXVIII, No. 1763. 4° London, 1893.

Colliery Guardian. Vol. LXV, No. 1694 to LXVI, No. 1706. Fol., London, 1893.

Geographische Abhandlungen. Band V, heft 3. 8° Wien, 1893.

Geological Magazine. New series, Decade III, Vol. X, Nos. 7-8. 8° London, 1893.

Indian Engineering. Vol. XIV, Nos. 1-12. Flsc., Calcutta, 1893.

PAT. DOYLE.

Industries and Iron. Vol. XV, Nos. 1066-1078. 4° London, 1893.

London, Edinburgh, and Dublin Philosophical Magazine, and Journal of Science. 5th series, Vol. XXXVI, Nos. 218-220. 8° London, 1893.

Mining Journal. Vol. LXIII, Nos. 3016-3028. Fol., London, 1893.

Natural Science. Vol. II, No. 13. 8° London and New York, 1893.

Nature. Vol. XLVIII, Nos. 1233-1245. 4° London, 1893.

Neues Jahrbuch für Mineralogie, Geologie und Palæontologie. Band II, heft 1. 8° Stuttgart, 1893.

Oil and Colourman's Journal. Vol. XIV, Nos. 155-157. 4° London, 1893.

Palœontographica. Band XL, lief. 3-4. 4° Stuttgart, 1893.

Palæontologische Abhandlungen. Neue Folge, Band II, heft. 2. 4° Jena, 1893.

Petermann's Geographischer Mittheilungen. Band XXXIX, Nos. 6-8. 4° Gotha, 1893.

THE EDITOR.

Scientific American. Vol. LXVIII, Nos. 22-25; and LXIX, Nos. 1-9. Fol., New York, 1893.

Scientific American. Supplement. VOL. XXXV, No. 909 to XXXVI, No. 921. Fol., New York, 1893.

The Indian Engineer. Vol. XVII, Nos. 325—336. 4° Calcutta, 1893.

J. MACINTYRE.

The Pioneer. New series, 1st Edition, July to September 1893. Fol., Allahabad, 1893.

schermak's Mineralogische und Petrographische Mittheilungen. Band XIII, heft 1—2. 4° Wien, 1893.

Repertorium und General Register der Zeitschrift für Krystallographie und Mineralogie. By P. Groth and F. Grünling. Theil II. 8° Leipzig, 1893.

Zeitschrift für Krystallographie und Mineralogie. By P. Groth. Band XXI, heft 5-6, and XXII, heft 1. 8° Leipzig, 1893.

GOVERNMENT SELECTIONS, REPORTS, ETC.

BENGAL.—Discovery of the exact size of Asokas Classic Capital of Pataliputra, the Palibothra of the Greeks and description of the superficial remains. By L. A. Waddell, M.B. 4° Calcutta, 1892.

BENGAL GOVERNMENT.

Titles of Books. *Donors.*

BOMBAY.—Selections from the Records of the Bombay Government. New series, Nos. 267, 268 and 270. Flsc. Bombay, 1893. BOMBAY GOVERNMENT.

BURMA.—Twenty-sixth Annual Report on the Light-Houses and Light-Vessels off the Coast of Burma for the year 1892-93. Flsc. Rangoon, 1893.
CHIEF COMMISSIONER OF BURMA.

INDIA.—Administration Report of the Marine Survey of India for the year 1892-93 Flsc. Bombay, 1893. MARINE SURVEY DEPARTMENT.

„ Administration Report on the Railways in India for 1892-93. Part I. Flsc. Simla, 1893. GOVERNMENT OF INDIA.

„ Census of India, 1891.
Vol. I. General Tables for British Provinces and Feudatory States. Flsc. London, 1892.
„ III. The Report, and
„ IV. Administrative Tables of the Lower Provinces of Bengal and their Feudatories. Flsc. Calcutta, 1893.
„ V. The Lower Provinces of Bengal and their Feudatories. The Caste tables. Flsc. Calcutta, 1893.
REVENUE AND AGRICULTURAL DEPARTMENT.

„ Government of India. Civil Budget Estimates for the year 1893-94. Flsc. Calcutta, 1893. GOVERNMENT OF INDIA.

„ List of Civil Officers holding Gazetted appointments under the Government of India in the Home, Legislative, Foreign and Revenue and Agricultural Departments, corrected to 1st January 1893. 8° Calcutta, 1893.
GOVERNMENT OF INDIA.

„ List of Officers of the Geological Survey of India, corrected to 1st July 1893. 8°. Pam. Calcutta, 1893.
REVENUE AND AGRICULTURAL DEPARTMENT.

„ Quarterly Indian Army List. New series, No. 16. 8° Calcutta, 1893.
GOVERNMENT OF INDIA.

„ Cyclone Memoirs, No. V. Account of three cyclones in the Bay of Bengal and Arabian Sea during Nov. 1891. 8° Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ India Weather Review, Annual Summary, 1892. 4°. Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Monthly Weather Review for February to April 1893. 4°. Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA

„ Rainfall Data of India, 1892. Flsc. Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

„ Register of Original Observations, reduced and corrected, February to April 1893. 4° Calcutta, 1893.
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Report on the Administration of the Meteorological Department of the Government of India for 1892-93. 4° Calcutta, 1893.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

LONDON.—First, Second, Third, Fourth and Final Reports of the Royal Commission appointed to inquire into the subject of Mining Royalties, 1890—1893. Flsc. London, 1890—1893.
REVENUE AND AGRICULTURAL DEPARTMENT.

Titles of Books. *Donors.*

MADRAS.—Madras Meridian Circle Observations, 1877 to 1879. 4° Madras, 1893.
MADRAS GOVERNMENT.

„ Report on the several schemes—Hebbal-Rachenhalli-Hessar-Ghatta-Maligal Valley—for the water-supply of the Civil and Military Station and City of Bangalore. Flsc. Bangalore, 1893. MAJOR GRANT.

PUNJAB.—Final Report of the Revised Settlement of the Rawalpindi District in the Punjab, 1880—1887, with maps, by F. A. Robertson. Flsc. Lahore, 1893.
PUNJAB GOVERNMENT.

„ Final Report on the Revision of Settlement (1884—1889) of the northern part of the Ferozepore District in the Punjab. Flsc. Lahore, 1893.
PUNJAB GOVERNMENT.

„ Gazetteer of the Ambala District, 1892-93. 8° Lahore, 1893.
PUNJAB GOVERNMENT.

„ Gazetteer of the Gurdaspur District, 1891-92. 8° Lahore, 1893.
PUNJAB GOVERNMENT.

TRANSACTIONS, PROCEEDINGS, ETC., OF SOCIETIES, SURVEYS, ETC.

ADELAIDE.—Transactions of the Royal Society of South Australia. Vol. XVI, pt. 2. and XVII, part 1. 80° Adelaide, 1893. THE SOCIETY.

ALBANY.—Geological Survey of the State of New York. Palæontology. Vol. VIII, part 1. By James Hall. 4° Albany, 1892. THE SURVEY.

ALGIERS.—Explication Carte Géologique de l'Algérie, with map. 4° Algiers, 1890.
GEOLOGICAL SURVEY, ALGIERS.

BALTIMORE.—American Chemical Journal. Vol. XIV, Nos. 2—7. 8° Baltimore, 1892.
JOHNS HOPKINS UNIVERSITY.

„ American Journal of Philology. Vol. XII, No. 4, and XIII, Nos. 1—3. 8° Baltimore, 1891. JOHNS HOPKINS UNIVERSITY.

„ Johns Hopkins University Circulars. Vol. XII, Nos. 106—107. 4° Baltimore, 1898. JOHNS HOPKINS UNIVERSITY.

„ Johns Hopkins University Studies in Historical and Political Science. 10th series, Nos. 4—11. 8° Baltimore, 1892.
JOHNS HOPKINS UNIVERSITY.

BATAVIA.—Nederlandsch-Indisch Plakaatboek, 1602—1811. Deel XI. 8° Batavia, 1893.
BATAVIAN SOCIETY.

BERLIN.—Abhandlungen der königlich Preussischen Geologischen Landesanstalt. Neue Folge, heft 6—8 and 13. 8° Berlin, 1893. THE INSTITUTE.

„ Abhandlungen zur Geologischen Specialkarte von Preussen und den Thüringischen Staaten Band. X, heft 4. 8° Berlin, 1893.
THE INSTITUTE.

„ Sitzungsberichte der König. Preuss. Akad. der Wissenschaftern zu Berlin. Nos. 41—55. 8° Berlin, 1892. THE ACADEMY.

„ Zeitschrift der Deutschen Geologischen Gesellschaft. Band XLIV, heft 4 and XLV, heft 1. 8° Berlin, 1893. THE SOCIETY.

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BOMBAY.—Journal of the Bombay Branch of the Royal Asiatic Society. Vol. XVIII, No. 49. 8° Bombay, 1893. THE SOCIETY.

" Journal of the Bombay Natural History Society. Vol. VII, No. 5, and VIII No. 1. 8° Bombay, 1893. THE SOCIETY.

BRESLAU.—Jahres-Bericht der Schlesischen Gesellschaft für Vaterlandische Cultur, No. 70, and Supplement heft 2. 8° Breslau, 1893. THE SOCIETY.

BRISTOL.—Proceedings of the Bristol Naturalists' Society. New series, Vol. VII, part 2, and List of Officers, etc. 8° Bristol, 1893. THE SOCIETY.

BRUSSELS.—Bulletin de la Société Royale Belge de Géographie. Année, XVI, No. 6. 8° Bruxelles, 1893. THE SOCIETY.

BUDAPEST.—Természetrajzi Fuzetek. Vol. XVI, Nos. 1—2. 8° Budapest, 1893. THE HUNGARIAN NATIONAL MUSEUM.

CAEN.—Bulletin de la Société Linnéenne de Normandie. 4th series, Vol. VI, fasc. 1—2. 8° Caen, 1893. THE SOCIETY.

CALCUTTA.—A Manual of the Geology of India, 2nd edition. By R. D. Oldham. 8° Calcutta, 1893. GEOLOGICAL SURVEY OF INDIA.

" Palæontologia Indica. Series IX, Vol. II, part 1. 4° Calcutta, 1893. GEOLOGICAL SURVEY OF INDIA.

" Records of the Geological Survey of India, Vol XXVI, part 3. 8° Calcutta, 1893. GEOLOGICAL SURVEY OF INDIA.

" Epigraphia Indica of the Archæological Survey of India. Vol. II, part 13. 4° Calcutta, 1893. GOVERNMENT OF INDIA.

" Imperial Institute Series. Guides to Commercial Collections Indian Section. No. 1, Guide to Collections of 1892. 8° Calcutta, 1893. REPORTER ON ECONOMIC PRODUCTS TO THE GOVERNMENT OF INDIA.

" Journal of the Asiatic Society of Bengal. Vol. LXII, Part I, No. 2; Part II, No. 2; and Title-page and Index for Part I of 1892. 8° Calcutta, 1893. THE SOCIETY.

" Proceedings of the Asiatic Society of Bengal. Nos. 6-7. 8° Calcutta, 1893. THE SOCIETY.

" Proceedings and Journal of the Agricultural and Horticultural Society of India from January 1892 to June 1893. 8° Calcutta, 1892-1893. THE SOCIETY.

" Survey of India Department Notes for June to August 1893. Flsc. Calcutta, 1893. SURVEY OF INDIA DEPARTMENT.

CAMBRIDGE, MASS.—Bulletin of the Museum of Comparative Zoölogy. Vol. XVI, No. 13, and XXIV, Nos. 4—6. 8° Cambridge, Mass., 1893. THE MUSEUM.

COPENHAGEN.—Mémoires de l'Académie Royale des Sciences et des Lettres de Danemark. 6me série, Tome VII, No. 7. 4° Kobenhavn, 1893. THE ACADEMY.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1894. [February.

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1893.

1. During the year, connected surveying was carried out in Baluchistan by Mr. Griesbach, assisted for a short time near the end of the field season by Mr. W. B. Edwards. Mr. LaTouche was occupied for the full season at the Bhaganwalla coal-field in the Salt Range, Punjab. In Hazara, Mr. Middlemiss, accompanied by Sub-Assistant Hira Lal, completed the survey in that part of the Punjab. Mr. Bose and Mr. Datta were engaged in Tenassarim on coal exploration; while Dr. Noetling, more directly in communication with the Local Government, was engaged on several enquiries in Upper Burma. Dr. Noetling was also engaged, just towards the end of the year, in reporting on the condition of the Dandot and Warora Collieries (in the Punjab and the Central Provinces) in view of a rather large percentage of accidents; a deputation which was of immediate necessity, the awaited Inspector of Mines not having at the time arrived in India. Mr. F. H. Smith and Sub-Assistant Kishen Singh were at work in the Rewa State, where surveying was done in connection with the mineral exploitation left by Mr. Hughes in the hands of the State Mining Assistant, Mr. Sewell. In the Madras Presidency, field petrology and mineral survey were carried out by Mr. Holland at such times as he could be spared from the Laboratory and Museum at Calcutta, and his Professorial work at the Presidency College. Mr. Oldham remained at head-quarters for the greater part of the year, engaged on the preparation of the new edition of the Manual of the Geology of India which was published in August. He was, however, able to pay a short visit to Burma in March when he enquired into and reported on the prospects of an artesian water-supply for Rangoon; and also inspected the oil region of Yenangyoung and that neighbourhood regarding an apparent tendency to a decrease in the well supplies, which was happily not confirmed. I myself was on tour in March and April at Sukkur and Karachi in connection with the proposed experimental oil-boring at the former place, and at the Salt Range coal-fields: in April and May, I had an opportunity of conferring with the Financial Commissioner at Rangoon on the gold enquiry in the Kathá district and inspected the coal exploitation on the Tenassarim river; and after return to Calcutta proceeded to Warora Colliery in the Central Provinces to advise the Manager on some deep borings which were being carried out in a new part of the field. In September and October, I visited parts of Madras, examining

certain areas of hypersthenic igneous rocks, lately brought to notice by Mr. Holland; and arranged with the Government for a more connected mineral survey of the Salem district: and at the end of the year a further visit was made to Burma to examine the conditions of the Kathá gold occurrences, and the capabilities of the Tingadaw coal-field.

2. The operations of the Survey have thus been mainly confined to extra-Peninsular India; that is, in the Punjab, the North-West Frontier, and Burma; while a small, though at the same time very important, advance has been made in Peninsular geology.

EXTRA-PENINSULAR GEOLOGY.

3. BALUCHISTAN.—*Tertiary* and *Cretaceous*.—A large tract of country in the Harnai valley has been added on to that already surveyed and reported on by Mr. R. D. Oldham in 1892, in his *Geology of Thal Chotiali and part of the Mari country;* and Mr. Griesbach has given a portion of the results of this later work in his paper on the *Geology of the country between the Chuppar Rift and Harnai.* We have thus a completely mapped and reported record of the area extending from the neighbourhood of Sibi to Mangi, along the line of the Sind-Pishin Railway. His survey, however, covered a far larger area than this, as it extended on to and around Quetta, dealing especially with the completer examination of the coal outcrops in the latter region; and over the Kojak-Zhob line of country, where he came across a very interesting zone of volcanic instrusions among the lower eocene rocks.

4. Mr. Griesbach was the first member of the Survey who entered on the Bolan-Quetta ground so far back as 1880, though then only by traverse work alongside of the military occupation of the country, so that his interpretations, which sometimes extended on either side well beyond his line of march, were necessarily sketchy and so far open to a certain amount of criticism by his then senior officer, Mr. W. T. Blanford, who, armed already with his wide experience of the Sind cretaceo-tertiaries, followed pretty much on the same track to Quetta and out again by the Harnai route in 1881-82. Blanford's march was also a traverse, and he was harassed by illness over the latter part of his journey. The subsequently settled and railway-opened-up condition of the country eventually permitted of a more detailed survey being made, though this was interrupted at times by excursions after coal and oil; and Mr. Oldham was deputed for the work the results of which he gave in the report referred to above, the principal one being that there is an absence of definite break between the eocene and cretaceous formations; that there is, in fact, considerable indication of a series of passage beds. With the evidence of his two colleagues before him, the later observer is therefore fortunate in having the opportunity of settling the geology of this interesting region—interesting not only in its structural relations, but as being a connecting area between the Europe-Persia tract and the Indian extension of the ancient Mediterranean area of cretaceo-tertiary life and deposition. The question of the relations between our Indian tertiaries and the cretaceous formation is indeed of the greatest interest to geological science, because, whereas in England and Western Europe the distinction between the two is absolute straligraphically and palæontologically, the evidences in Eastern Europe and thence eastward are

much less pronounced in that connection. In Peninsular India, it has long been known that the *quasi*-cretaceous facies of certain fossiliferous beds associated with the Deccan Trap Series, as well as other characteristics, point very decidedly to a period of passage life and volcanic activity; and our later progress in the Punjab and in Baluchistan appears to be more and more confirmatory of this.

5. So far, however, Mr. Griesbach is not able, on the stratigraphical and fossil evidence obtained by him, to follow Mr. Oldham, in his exposition of a passage series characterised by an anomalous fauna, in the Harnai valley, preferring to consider that Mr. Oldham's "Dungan Beds" are really of lower eocene age; an examination of the fossils (*Crioceras*, *Baculites* and *Ammonites*, with an abundance of *Nummulites*) by Dr. Nœtling showing rocks yielding them to be of true cretaceous—rather lower than upper-age, with *Orbitolites;* no nummulite being recognizable in the collection sent down to Calcutta. The question, therefore, still remains an open one for Mr. Griesbach to work out during his further progress on the Baluchistan survey: although the balance of evidence, outside of this fossil case, as displayed generally over the Harnai-Thal Chotiali tract and in the Western Punjab hills, is still considerably in favor of a passage series. Indeed, only lately, in December, a note has come in from Dr. Nœtling, who has been engaged on a mining inspection of the Dandot colliery in the Salt Range, wherein he mentions that on examining the coal shale basin underlying the nummulitic limestone, he had found the fossils having a decided tertiary facies, but that there were among them others with an upper Senonian (White Chalk) aspect; so that here again is a further item in the evidence for a passage series. A presumed corrolation of the dark shales of the Kojak range with the Simla slates (attributed to carboniferous age by Mr. Oldham) has been corrected so far by Griesbach's finding within them a true nummulitic bed, thus adding confirmatory evidence to his original view of the tertiary age of the Kojak series.

6. PUNJAB: SALT RANGE.—The nature of Mr. LaTouche's duties in connection with the boring exploitation in the Bhaganwalla coal-field prevented his devoting much time and attention to geology except in the immediate vicinity of his work; he was therefore unable to add much to the discussions of the numerous interesting problems which have arisen since the time of Mr. Wynne's splendid work in that area.

7. *Palæozoic.*—The strange occurrence of the comparatively soft series of the Salt-marl group, generally underneath a very thick and massive series of older palæozoic age; and again in apparent natural position under yet newer formations has, within the last few years, aroused under Mr. Middlemiss' and my own study, much discussion not only as to its position but as to its origin. This series is, however, only very slightly exposed in the gorge at Bhaganwalla, and its relations with the overlying purple sandstone are only clearly seen at one point, on the right bank of the stream immediately above the village. Mr. LaTouche observed that the appearance of injection into the overlying sandstones is certainly noticeable, but it does not seem impossible that this appearance may have been caused by a squeezing out of the soft marl along the line of a fold.

8. *Cambrian.*—The "Silurian shales" of Wynne, which, however, ultimately yielded remains of trilobites at Khusak, thus determining their Cambrian age, are exposed on the right bank of the more westerly of the two streams which issue

from the range at Bhaganwalla, and Mr. LaTouche was fortunate enough to discover specimens of trilobites in an identically similar position to that in which they occur at Khusak, *viz.*, in a band of dark shale, a few feet below the base of the Magnesian Sandstone. The specimens were in the same state of preservation as at Khusak, only heads being found; and no additional species were discovered. They occurred here in only this single zone, the lower "galleries" of Khusak being apparently unrepresented.

9. *Permo-carboniferous.*—The "Boulder Bed," so conspicuous in the middle portion of the southern escarpment of the Salt Range, is not well-developed near Bhaganwalla; occurring only in lenticular patches, never more than a few feet in thickness, between the white sandstones at the base of the coal-bearing group (tertiary) and the "Salt Pseudomorph" zone of Triassic age. No unconformity could be detected between it and the beds above and below; indeed it appears to pass up into the white sandstones, the base of which sometimes contains strings and thin beds of pebbles and small boulders, similar to those in the boulder bed proper.

10. *Cretaceous-eocene.*—In describing the existence of fossil resin in the coal, which is considered so far to be of tertiary age, Mr. LaTouche recalls the fact that in Assam, where coal seams occur in beds of both cretaceous and nummulitic age, an exactly similar fossil resin is found, but only in the coal of cretaceous age, which it serves to distinguish from the newer nummulitic coal. If, as seems likely, this resinous substance points to some peculiarity in the vegetation from which the coal was formed, its occurrence in beds of different ages in the two areas would seem to indicate either that the coal-producing vegetation of cretaceous age in Assam persisted to nummulitic times in the Punjab, while it was replaced by a different vegetation in the former province, or that the nummulitic coal of the Punjab is really homotaxial with the cretaceous coal of Assam—a supposition which its position, at the base of the nummulitic limestone (instead of overlying it as the nummulitic coal of Assam does), and the absence of any break in deposition between the beds of the two ages in both areas, renders not unlikely.

11. *Upper Tertiary.*—Regarding the questions of the relations of the Nummulitics to the Nahans, no signs were observed of unconformity. The transition is always abrupt, and pebble beds are of frequent occurrence at and near the base of the sandstones, but the rolled pebbles are always of crystalline rocks, and do not include any from the underlying limestone. Nodules of the latter are of occasional occurrence in the lowermost beds of the Nahans, but, so far as was seen, they are not rolled, and do not form anything like a pebble bed. Their occurrence, however, imbedded in the sandstones, shows that before the deposition of the latter, the limestone had assumed its present highly nodular structure and therefore would appear to indicate the lapse of a considerable period of time between the laying down of the two formations.

12. HAZARA.—The cold weather of 1893 brought to a close Mr. Middlemiss' three seasons' work in Hazara. During that time the chief objects of the re-survey were to fill in the gaps in the maps left unfinished by Mr. Wynne, dated 1877-79, and to link together the scattered information on the subject to be found in the Records and Memoirs of the Geological Survey, by supplying an organised account of the whole district. These objects have in the main been attained, and as on nearly all important points the work harmonizes with that of Dr. Waagen and

Mr. Wynne, their classification of the historical rocks has been adopted. The following is a list of the Geological formations represented in Hazara, in descending order :—

(1) Alluvium and Recent gravels.
(2) Murree beds, *Miocene.*
(3) Kuldana beds (=passage beds).
(4) Nummulitic, *Eocene.*
(5) *Middle Cretaceous.*
(6) *Jurassic.*
(7) *Triassic.*
(8) *Infra-Trias.*
(9) Slate Series

13. In the northern parts of Hazara certain rocks are invaded by lenticular beds of gneissose-granite, the result being a complex of crystalline and metamorphic rocks, which occupy large areas among the secluded mountains and glens of Agror, Khagan and the Black Mountain. One of the points to which Mr. Middlemiss' attention was chiefly directed was to settle if possible how many of the formations enumerated above had been affected by metamorphism during this irruptive period. The results show that the Infra-Trias and the Slate Series have been so affected to the exclusion of the rest. The various stages of metamorphism and the complicated mode of intrusion of the gneissose-granite offer many points of great interest which will be fully described in the forthcoming memoir on Hazara. The identity of character of these rocks with those of a great part of the Himalayan range is important as implying a unity of age and structure.

14 As regards the distribution of the formations over the surface of the country, there is a natural scheme into which they fall, *viz.*, a set of zones or elongated strike areas, each of which is characterised by the prevalence at the surface of a particular formation. There are many other peculiarities defining these zones which will be given in detail in the memoir, but one particularly striking feature is that each of these zones is divided from its neighbour-zone by a long fold-fault extending generally the whole breadth of Hazara. The following is a list of the zones from N.W. to S.E :—

I.—Younger Tertiary Zone.
II.—Nummulitic Zone.
III —Slate Zone.
IV.—Crystalline and Metamorphic.

As to what these formation-zones, which are also disturbance-zones, means; it is believed that they have important bearings on the history and development of the great mountain ranges, portions of which lie within the boundaries of Hazara.

15. The district has not yielded any fine collections of fossils comparable to those of the Salt Range or the Central Himalaya, but from the cretaceous band a good number of forms have been gathered which without much difficulty can be matched by those from the cretaceous of Southern India at about the horizon of the Utatur group. The geological mapping of the area has been done on the sheets of the Revenue Survey (1 inch = 1 mile), and a map is being prepared for publication on half the above scale. Horizontal sections will accompany the map, and panoramic views of the country, drawn with the camera lucida, and colored geologically, will be added, so as to present the rock structure and physical features of the country together at a glance.

16. Lower Burma.—*Palæozoic* and *Tertiary*.—While engaged at the exploitation for coal on the Great Tenassarim river, Messrs. Bose and Datta had necessarily to devote a considerable part of their time to working out the geology of that part of Tenassarim; and mainly because the mineral itself appeared to be of different quality in separate places, while it is at the same time associated with two different series of rocks. As a matter of fact, the coal is of two ages, the older but poorer coal being of carboniferous age, while the latter of the two is of tertiary age. In this enquiry, we have now obtained a fairly connected knowledge of the geology of Tenassarim from Victoria Point, the southern limit of the country, up to the parallel of Mergui.

17. Dr. Oldham's original conclusion as to the carboniferous age has been further established through Mr. Bose's find of a series of true carboniferous fossils in one of the strangely picturesque and cavernous isolated ridges of limestone so frequently met with in Moulmein, Tavoy, and Mergui; though until now, never in such close association with the strata carrying the poorer coal referred to above, He was also able to determine the much later (tertiary) age of the series (Tendaw) containing the proper workable coal; this particular development of which forms a shallow synclinal basin lying along the bottom of the main river valley, which has been excavated in one of the great anticlinal folds into which the palæozoic series of Tenassarim has been thrown, and which extends—marked by bands of cavernous limestome—with a fairly north and south strike through the districts of Tavoy and Amherst and thence northwards into Upper Burma.

18. Upper Burma.—*Palæozoic and Tertiary*.—The same carboniferous series was met with by Dr. Noetling far to the north in Mogaung and Bhamaw, whence he has been able to connect it past Mandalay, Yamethin, Toungoo, and Shwegyin, with the cavernous limestones of Moulmein, which country he was able to visit early in the season. He also examined the Moulmein caves for remains of bone-bearing gravels, traces of which he had already found in the Irrawaddi valley, but so far without success. His work during the season was however principally in connection with the oil and mineral developments of the country, particularly around Wuntho in the Kathá district, which he examined for gold, lead and coal. This is a large area of about 2,000 square miles in extent and mainly covered with jungle, so nothing but traverse observations could be made and the general position and lie of the rocks ascertained. The formations met with were palæozoic limestones (already mentioned as extending northwards in this district) on the extreme east of the present area; lower and upper mesozoics, and the alluvium in a wide bay on which lies the town of Wuntho, and in the Mu river valley. The latter valley is bordered on its eastern side by north-north-east—south-south-west striking belts of two miocene groups, in the lower of which good coal seams are found in blue shales. They resemble so closely the coal measures in the Chindwin district that there can be little doubt as to their being of the same geological period. Several small outliers of the same series, though without indications of coal, are scattered over the Wuntho alluvial plain, and a wider and fuller development constitutes the low hill tract to the eastward. The middle region—that is, the lofty hilly tract of Mankaw (3,911 ft.)—is made up of a wide expanse of schists and trappoid rocks in which are frequent traces of poorly auriferous occurrences in the diorites themselves, and in some of the quartz veins distributed through this series, the age of which has not yet been ascertained with any degree of certainty.

PENINSULAR GEOLOGY.

19. MADRAS.—*Crystalline series.*—As was the case last year, investigation of the crystalline series has only been carried out as opportunity offered when Mr. Holland could be freed from his proper duties. In this way, he was able to pay visits during the months of May and June, and again in part of September and October, during the first of which he was at last able to carry his experiences of Salem into the Coimbatore and Nilgiri districts. The Nilgiris had been surveyed so far back as 1857, at which time the study of the metamorphic crystalline rocks was still, owing to their presenting a certain laminated and even, in cases, a decidedly bedded structure, biassed with a tendency to consider them as a highly altered form of sedimentary deposits; while investigation as to their composition and the aggregation or mode of occurrence of their mineral constituents was as yet only open to but an initial stage of the splendid microscopical research which has since developed into the specialized science of petrology. Thus, though somewhat against the views of the then Director (Dr. Oldham) of the Survey, these mountains, and later on, the Shevaroys and other hill masses in the Salem district, were finally considered to be made up of very highly altered massive gneisses of original sedimentary accumulation.

20. Step by step, however, new points of evidence have been brought together confirming Mr. Holland's original conclusion, referred to in my last annual report, that whatever may have been the origin of the materials now forming the principal part of the greater mountain masses of Southern India, their mineral composition and microscopic structures which are so strikingly the same in widely separated and apparently isolated localities can only be the result of having been formed under conditions identical with those ordinarily regarded as belonging to igneous rocks. Rocks, indistinguishable in hand-specimens, occur at St. Thomas' Mount, in the hills near Pallavaram railway station, at Mailam, on the Shevaroy hills, the Nilgiris, the Pulnis, the Anaimalais and the Western Ghats which, in each district, contribute a complete pyroxenic series ranging from acid granites to very basic pyroxenites.

21. The occurrence of these rocks in India will doubtless yield suggestive evidence towards the solution of some of the larger questions which have of recent years occupied the attention of workers in the so-called archæan gneisses and schists with which in other parts of the world similar rocks have been found always associated; as in the cases of the trap-granulites of Waldviertel in Saxony, in the Hebridean gneissic system of Sutherlandshire and Aberdeen in Scotland; the norites of the "Cortlandt Series" and the gabbros of Baltimore in America. With regard to the Cortlandt Series of the latter country, the microscopic characters of which were described by Professor G. H. Williams, in a series of well-known papers published in 1886-87; almost every type described by that author has been matched in our recent survey by specimens from the Madras Presidency; in addition to which I may also announce the discovery of a distinctly acid pyroxene-bearing rock, which seems to be a type of igneous rock hitherto undescribed, the pyroxene being generally of the rhombic type, and approaching proto-hypersthene in composition. From this fact and because the rock, both in hand specimens and in field characters, presents an unmistakable individuality; Mr. Holland feels justified in describing it under the new name *Charnockite*, one of the first specimens of the rock (which is largely used for structural and ornamental purposes)

brought to Calcutta and the first examined under the microscope, being a splinter from the tombstone of Job Charnock (1693).

22. To complete the parallel with the American rocks : spinelloid *hercynite*, a constant associate of corundum, has been found among the other rather rare minerals in the Madras pyroxene series; and it is thus possible that the obscurity in which the origin of corundum still lies may be dissipated by the researches now being pursued in the field and laboratory.

23. That the petrological variety for which the Norwegian and Ural rocks have long been famed may be paralleled in India, as pointed out by Mr. Holland last year when announcing his discovery in India of the rare mineral *riebeckite*, appears to be well sustained by the evidence afforded by these rocks; yet we have even a later determination of what was supposed (by the sender) to be a piece of iron ore found in Bengal, as the rare mineral *columbite*, one of the characteristic niobates and tantalates of Scandinavia and the Urals. In this connection, too, is the very interesting discovery by an independent observer (Dr. J. W. Evans, State Geologist of Jonagadh in Kattiwar) of the remarkable rock, elœolite-syenite, known more especially from its occurrence in South Norway; where, as in India, it is associated also with angite-syenite.

ECONOMIC SURVEY.

24. Coal investigation has gone on in Baluchistan, the Salt Range in the Punjab, and in Tenassarim: while coal, oil, gold, and lead ores have been explored in Upper Burma. Lead enquiry has been carried out to some extent in Rewa; and the extended occurrence of corundum and the iron ores has received a certain amount of attention in the Madras Presidency.

25. The coal enquiry in Baluchistan had reference to the coal outcrops near Quetta, or more strictly speaking in the high valleys of Les and As Tangi to the eastward of that town, which have been under desultory working by native contractors, but which it was hoped might on closer survey be found worth working in a more systematic way. The detailed survey was undertaken by Mr. Assistant Superintendent Edwards under the orders of Mr. Griesbach, but the survey was not completed owing to the illness of the former officer which culminated in a severe attack of typhoid fever. The survey was again resumed by Mr. F. H. Smith in October last. In the meantime, Mr. Griesbach completed the survey on the Khóst side of the country when he was able to offer a much more sanguine opinion as to the future of the coal in that direction, and he has given details of the various sections exposed in the Harnai valley in his report of the country between the Chuppar Rift and Harnai which was published in the last part of the Records of the Survey, and from which I take his concluding remarks :—

Quetta Coal.

Harnai Coal.

"It only remains to add a few words on the economic value of the area. This, of course, consists in the large amount of coal which is available in the more or less constant horizon of the middle nummulitic subdivision. Most of the outcrops have either been worked or are sufficiently tested to prove the usefulness of the coal as regards quality and the limited thickness of the seams, and it is certain that even after the complete exhaustion of the Khóst collieries there will be a very large amount of coal left in other sections of the field. I will not enter here into the composition of the coal; this has been done already by other observers. Mr. Jones has also attempted to compute the quantity of coal available, but he has certainly

much under-estimated the latter. The fact is, no estimate, even approximately correct, can possibly be arrived at, which would be of the least practical use. The whole basin of the 'trough,' including the entire hill-range which bounds it along the southern rim, with probably a large area south of it, is part of the field and contains seams of coal. If only the Khóst seams are taken as examples and the amount of coal calculated on the thickness of these seams and the area of the basin, no doubt a fairly accurate idea of the amount of coal *present* in these strata would result; but that is not the amount actually available. The greater portion of the basin is broken up by faults, folds, and some of it has been carried away by denudation, so that only a small proportion of the total coal is available for mining purposes, and of these portions the exact limits are not known. In the above paper I have given a description of the distribution of the seams, and also indicated in outlines which I consider the most promising localities for opening works, after Khóst is exhausted or nearing that stage.

"Amongst the best of these localities is the cliff, 3½ miles south-east of Sháhrág Station, with the area immediately adjoining it. This will undoubtedly offer as good chances as did the Khóst workings, and the locality is near enough to the line of railway to be worked cheaply. Next to Sháhrág in importance, I consider the cliff between Púnga Ghát and Harnai; there the seams are good, but the outcrops are too low down the hill-side to allow the same process of mining to be adopted as at Khóst and Sháhrág. The workings would be soon below the level of the ground-water, and therefore pumping would have to be resorted to, which would increase the cost of the output considerably.

"Still more difficult to work, on account of the underground water, would be mines established on the Púnga Ghát, or north of the river near Ali Khan, were it decided to bore in these localities for coal, which most probably would be met with not far below the present surface."

26. The coal enquiry at Bhaganwalla in the Salt Range was instituted on account of a proposal by the North-Western Railway administration to work the Bhaganwalla area, the supply from the Dandot colliery to the westward being inadequate to meet the demand. Mr. Luckstedt, the Executive Engineer in charge of the coal operations, having made a report on what he considered to be the probable available amount of coal under the Ara plateau and in the eastward end of the Salt Range, which certainly appeared to me to be over-exaggerated; it was decided to test this by borings and detailed survey, for which duty Mr. LaTouche was deputed from the Survey. A detailed plane-table survey on a scale of 6 inches to the mile was made by Mr. Edwards; and, although the large area of the Ara plateau must be left out of consideration, as all the evidence goes to show that no continuous seam of coal can be expected to lie under it, it was found that at the eastern end of the range, where the coal suddenly becomes high-dipping, there is probably an available output of over a million tons, provided working can be carried on to a sufficient depth along the dip. Mr. LaTouche's report is given in full in the current part of the Records.

Salt Range Coal.

27. In Tenassarim, it was decided to test the Tendaw-Kamapying coal-fields, on the Great Tenassarim river, by a series of borings and pits, which were carried out by Mr. Bose assisted by Mr. Datta. The old interest in this field was revived by Mr. Hughes during his exploitation of the Tenassarim tin areas, a preliminary report having been published by him in the Records for 1892. Mr. Bose's report confirms the estimate of Mr. Hughes as regards the presumable quantity of available coal under not difficult working, *viz.*, about a million tons; and this is what may be called a safe estimate. Extended and somewhat more troublesome mining would probably disclose a larger

Tenasserim Coal.

amount of coal. Mr. Hughes relied on this further exploration as likely to show some extension of the coal-field considerably further southwards down this long reach of the Tenassarim river, but this has not been proved; indeed, the evidence obtained is decidedly against it. From my own inspection of this river's wonderfully zig-zag course through the frequently high-ridged tract of country between Mergui and the coal valley, I should say that there is little chance of finding an easily workable road or tram-track between the coal and the seaboard, while a route partly by land and partly by river would only involve a ruinous break of bulk in carriage of the fuel. Getting the coal to the coast solely by the river route seems inevitable; and this can only be done by barges and stern-wheel steamers of the shallowest draught.

Kathá gold tract.

28. In Upper Burma, Dr. Noetling reported on the occurrence of coal in the Pinlebu subdivision, Kathá district; on the lead-mines in the same subdivison; and on the auriferous tracts in Wuntho. With regard to the latter, he found on arriving at the place that very little was known as to the actual situation of the localities where gold was said to have been extracted from the ground by the natives. The chief importance of the meagre information that could be obtained consisted in the fact that everything tended to prove that the gold was not extracted from the alluvial formation, but that there actually existed veritable "reefs." But nothing could be ascertained as to their whereabouts, the natives apparently being very reluctant to give any information. The only information supplied was that Mr. Bidoulac had applied for, and been granted, a concession of $\frac{1}{4}$ square mile of land supposed to be gold-producing, near a village called Kokkotta, north of Wuntho. At least seven different localities were ultimately discovered where the natives used to dig for gold. However, the examination of the places was sufficient to form an opinion as to the occurrence of gold, so far as this could be done without extensive digging. Just at the end of the year, however, I have myself had an opportunity of inspecting this region, which is one of a schistose series, which may answer to our Dharwar series of Peninsular India. It is very extensively traversed by a complex of basic igneous rocks, and in certain belts, particularly where the schists are very talcose, there is a decided development of quartz infiltrations in the form of generally small reefs, ledges, and strings which are more or less auriferous. The whole area, covered as it is by fairly thick and lofty forest and subject to a moderately moist climate, is wonderfully decomposed as to its rocks, which are now, for considerable depths, little else but red and brown ferruginous, sometimes lateritic, clays, which however still show their original bedded or laminated structure in the deeper gullies and in some of the artificial excavations; and in this decomposed rock, or scattered over its slopes, may be seen the outcrops of strings and ledges, or the debris of these. As a consequence, there are several localities which have been extensively and cleverly washed for gold by the natives—more steadily in old times because tribute was then forcibly demanded in gold in this part of the country; but much less often now. I did not see, or hear the least evidence of, any quartz having been pounded up for gold-washing; the old washers simply sluiced the weathered rock in a primitive but effective fashion and then washed out the coarse gold. The present people think nothing of the fine gold which is obtainable more or less from almost every hand lump of the pyritous quartz debris when pounded in a mortar. The present development, of nearly eight months' standing, is as yet scarcely beyond the initial stage; no very decided well-

defined or continuous reef having been met with, though there are outcrops of biggish ledges the quartz of which is, however, not so rich as in the smaller strings. The poor show of quartz occurrences now reported may indeed be more frequent in thickness as they are followed in depth, or they may not: there is no evidence in either one or the other direction.

Pinlebu Coal.

29. For the Pinlebu coal, which occurs exclusively in the low hills skirting the western side of the Maingthong hill tract; the summary of Dr. Noetling's report is, that there is only a small number of seams, which are generally of very inferior quality, consisting chiefly of shaly coal: only in two cases is it probable that the thickness of workable coal comes up to five feet. Although the coal is of good quality, it may safely be said that the quantity is insufficient. Even if there were a considerable quantity of coal available, it is doubtful whether the distance of at least 32 miles from the nearest railway station would not prevent a successful exploitation, the cost of transport being too high. Under these circumstances, the coal seams in the Pinlebu subdivision may be considered as relatively of little value, except for local use.

Pinlebu Lead.

30. The lead-mines in the Pinlebu subdivision occur at two localities where the Shan settlers in the Maingthong hill tract have been extracting lead-ore for a considerable time past,—*viz.*, (*a*) Kaydwin, and (*b*) Mawkwin. At the former place several large and deep holes may be seen which have been driven from the river bank into the hill-side; work has, however, been stopped for some time. So far as can be noticed, the ore occurs in the cracks of a dyke of an igneous rock belonging to the aphanite group, of considerable thickness; at one place its thickness is not less than 20 feet. The ore being *cerusite*, is found in strings up to ¼ inch of thickness filling the cracks of the rocks all throughout. On assay it yielded 69·1 per cent. of lead and 33 oz. 16 dwts. 4 grs. of silver to the ton of lead. At Mawkwin, the dyke is considerably thinner, and the old workings are less extensive; the occurrence of the ore being, however, exactly the same as at Kaydwin.

31. So far as can be judged from the examination of these two localities without extensive diggings being undertaken, the diggings at Kaydwin and Mawkwin are situated on one and the same dyke, running approximately south-west—north-east. If the dyke should contain an equal quantity of ore strings at intermediate places, such an occurrence of this lead-ore would certainly have a considerable value. This, however, can only be settled by extensive diggings.

MUSEUM AND LABORATORY.

32. Mr. Holland, the Officer in charge of the Museum, has made considerable progress in the classification and microscopic description of the large series of rocks collected during former years by officers of the department and private individuals, and results obtained add greatly to our knowledge of the eruptive and crystalline rocks, which have recently proved to be of great petrological interest. Amongst features of noteworthy interest which have resulted from this work, may be mentioned the curious inclusions of heulandite, celadonite and glauconite in handsome green crystals of calcite, and a new variety of magnetite. The so-called "mica-traps," intrusive in the coal-bearing rocks of Raniganj, Karharbari, and Darjeeling, are found to be interesting types of an ultra-basic rock, mica-peridotite.

33. A large number of assays of ores and coals, and the determinations of minerals, have been published from time to time in the Records ; and in this work of the Laboratory as well as in the Museum, Mr. Holland reports most favourably of the carefulness and accuracy of the work done by the Museum Assistant, Mr. T. R. Blyth.

34. Mr. Holland has especially for the sake of students, written an Introduction to the Study of Indian Minerals, with a descriptive list of the species represented and an Index to the Museum collection.

35. *Survey publications.*—A new edition of the Manual of the Geology of India has been revised and largely rewritten by Mr. R. D. Oldham and published during the year, which has been very favourably received. The progress of survey since the first edition was issued, has been so marked that an entire change has been made in the arrangement of the book, the rocks being described, in chronological order instead of being treated under a series of descriptions of separate districts. Still, many districts have had to remain untouched, so that as regards these, and where no serious modifications were necessary, the original text has been allowed to stand. The number of plates, maps, and page illustrations has been considerably increased, and the volume itself is in handier form. The year's volume of the Records contains 15 papers and appendices, of which six deal with industrial and allied subjects. In the Palæontologia Indica, Dr. G. W. Gregory's volume on the Jurassic Echinoidea of Cutch has been issued.

36. *Library.*—The additions to the Library amounted to 1,938 volumes or parts of volumes, of which 1,209 were acquired by presentation and 729 by purchase.

37. *Personnel.*—Mr. T. W. H. Hughes, through a most regrettable accident, was compelled to take leave from the 26th January 1893. Mr. R. D. Oldham has taken furlough from the 18th July 1893. Mr. W. B. D. Edwards has also, through illness, been granted leave from the 4th November 1893.

WILL. KING,
Director, Geological Survey of India.

CALCUTTA:
31st January 1894.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1893.

ADELAIDE.—Royal Society of South Australia.
ALGIERS.—Geological Survey of Algiers.
BALLARAT.—School of Mines.
BALTIMORE.—Johns Hopkins University.
BATAVIA.—Batavian Society of Arts and Sciences
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
„ Royal Prussian Academy of Science.
„ Royal Prussian Geological Institute.
BOMBAY.—Bombay Branch of the Royal Asiatic Society
„ Marine Survey of India.
„ Meteorological Department, Government of Bombay.
„ Natural History Society.
BOSTON.—American Academy of Arts and Sciences
„ Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Royal Geographical Society of Australia.
„ Royal Society of Queensland.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Malacological Society of Belgium.
BUDAPEST.—Hungarian Geological Institute.
„ Hungarian National Museum.
BUENOS AYRES.—National Academy of Sciences, Cordoba.
CAEN.—Linnæan Society of Normandy.
CALCUTTA.—Agricultural and Horticultural Society of India.
„ Asiatic Society of Bengal.
„ Editor, *The Indian Engineer*.
„ „ *Indian Engineering*.
„ Meteorological Department, Government of India.
„ Reporter on Economic Products, Government of India.
„ Survey of India.
CAMBRIDGE.—Philosophical Society.
„ University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Vereins fur Naturkunde.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
DIJON.—Academy of Sciences.
DRESDEN.—Isis Society.
„ Royal Mineralogical, Geological, and Pre-Historic Museum.
DUBLIN.—Royal Irish Academy.
„ Science and Art Museum.
EDINBURGH.—Geological Society.

EDINBURGH.—Royal Scottish Society of Arts.
,, Royal Society
,, Scottish Geographical Society.
FREIBURG.—Natural History Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Glasgow University.
,, Philosophical Society.
GOTHA.—Editor, *Petermann's Geographische Mittheilungen.*
GÖTTINGEN.—Royal Society.
HALLE.—Natural History Society.
HAMILTON.—Hamilton Association.
KONIGSBERG.—Physikalisch-Okonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Sciences.
LEIPZIG.—Verein für Erdkunde (Geological Society).
LIÈGE.—Geological Society of Belgium.
LILLE.—Société Géologique du Nord.
LISBON.—Geological Commission, Portugal.
,, Geological Survey, Portugal.
LIVERPOOL.—Geological Society.
LONDON.—Geological Society.
,, Iron and Steel Institute
,, Linnæan Society of London.
,, Royal Geographical Society.
,, Royal Institute of Great Britain.
,, Royal Society.
,, Society of Arts.
,, Zoological Society.
LYONS.—Museum of Natural History.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
,, Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria
,, Royal Society of Victoria.
MILANO.—Italian Society of Natural Sciences.
MONTREAL.—Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAPLES.—Royal Academy of Science.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
NEW YORK.—Academy of Sciences.
OXFORD.—University Museum.
OTTAWA.—Geological and Natural History Survey of Canada.
PARIS.—Editor, *Annuaire Géologique Universel.*
,, Geographical Society.
,, Geological Society of France.
,, Geological Survey of France.
,, Mining Department.

PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
,, Wagner Free Institute of Science.
PISA.—Society of Natural Sciences, Tuscany.
QUEBEC.—Literary and Historical Society.
RICHMOND.—Virginia University.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Geological Survey of Italy.
,, Royal Academy.
SAINT PETERSBURG.—Geological Commission of the Russian Empire.
,, Imperial Academy of Sciences.
,, König. Russische Mineralogische Gesellschaft.
SALEM.—American Association for the Advancement of Science.
,, Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch of the Royal Asiatic Society.
SYDNEY.—Australian Museum.
,, Department of Mines and Agriculture, New South Wales.
,, Geological Survey of New South Wales.
,, Linnæan Society of New South Wales.
,, Royal Society of New South Wales.
TOKIO.—Asiatic Society of Japan.
,, Deutsche Gesellschaft für Natur und Völkerkunde.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
,, Royal University.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Geological Institute.
,, Imperial Natural History Museum.
,, Royal Academy of Science.
WASHINGTON.—National Academy of Sciences.
,, Smithsonian Institution.
,, United States Department of Agriculture.
,, United States Geological Survey.
,, United States Mint.
,, United States National Museum.
WELLINGTON.—Colonial Museum and Geological Survey of New Zealand.
,, New Zealand Institute.
,, The Minister of Mines, New Zealand.
YOKOHAMA.—Asiatic Society of Japan.
,, Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Natural History Society.

The Governments of Bengal, Bombay, India, Madras, Perak, and Punjab.
The Chief Commissioners of Assam, Burma, and Central Provinces.
The Resident at Hyderabad.

Report *on the* Bhaganwala Coal Field, Salt Range, Punjab, *by* Tom. D. LATOUCHE, B.A., *Deputy Superintendent, Geological Survey of India. (With map and 2 plates.)*

Situation of the field.

This coal-field is situated near the eastern end of the Salt-Range, on the plateau overlooking the village of Bhaganwala, which lies at the foot of the range at about 10 miles to the north-east of Haranpur station, on the Sind-Sagar Railway, on the right bank of the Jhelum. It occupies a roughly triangular area, as shown in the accompanying plan, of about 7 square miles in extent, of which only the western portion, for the most part covered with alluvium, and highly cultivated, can be described as a plateau, while the eastern portion is hilly and cut up by deep ravines. Several small villages are situated on the plateau, the largest being Ara, which might have given its name to the coal-field, lying as it does in the centre of it, with more propriety than Bhaganwala.

Boundaries.

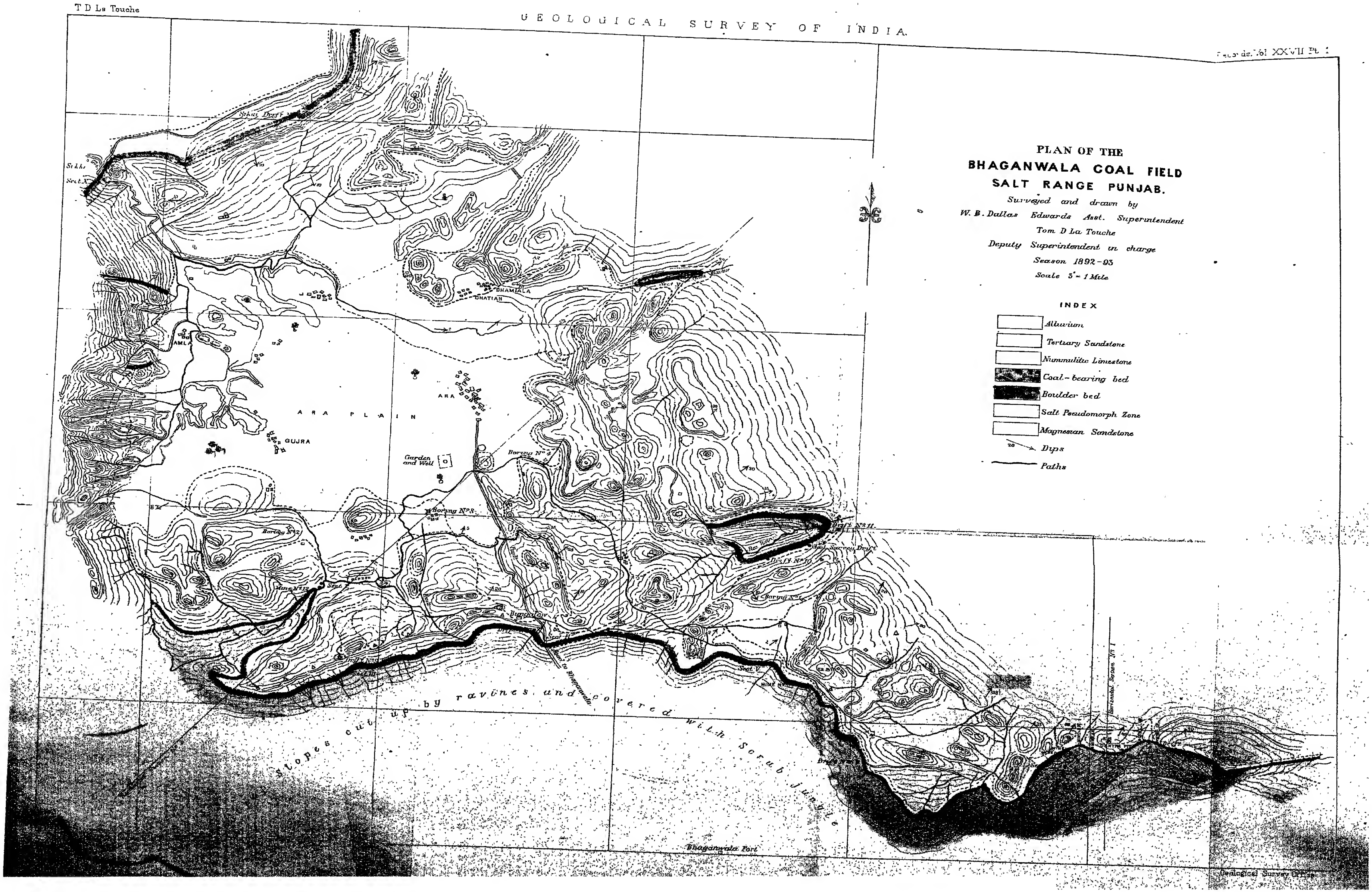
The area now to be described is only a small portion of the larger plateau, called by Mr. Wynne in his Memoir on the Salt-Range,[1] the "Eastern Plateau," which extends along the top of the range for a great distance towards the west, and it is quite possible that large deposits of coal may exist in that direction, besides those already worked at Pidh and Dandot; but so little has yet been done in searching the intervening ground, though indications of coal have been met with in several places, that this larger area may be left out of account at present. A zone of broken and hilly ground, due to sharp folding and faulting of the rocks, rising abruptly from the western edge of the alluvial flat on which Ara is situated, conveniently divides the coal-field from the larger plateau on the west, while on the north it is bounded by a broad and deep ravine, which cuts down into beds underlying the coal-bearing rocks. On the south it is bounded by the long line of scarp overlooking the plains of the Jhelum valley, and extending for about 5 miles from east to west; and to the north-east by a tract of very hilly country, occupied by highly inclined beds of sandstone and clays, higher in the series than the nummulitic limestone overlying the coal-bearing beds, so that the latter in this direction quickly become buried to an unworkable depth.

Previous notices.

Although it is only quite recently that a serious attempt has been made to open out the coal seams in this field, the fact of the existence of coal here has been known for many years. It appears to have been first brought to notice by Dr. Fleming in 1853 and was reported on by Dr. Oldham in 1864. Dr. Oldham estimated the total quantity of coal available at 16,20,000 maunds, or between 50,000 and 60,000 tons; but there is little doubt that a considerable quantity of coal, which was not included by Dr. Oldham in his estimate, as he considered that it lay at too high an angle to be profitably worked at any rate below the level at which it could be reached by horizontal adits, can be extracted, if proper precautions are taken in opening out the mines.

The coal of this locality is mentioned by Mr. Wynne in his Memoir on the Salt-Range above cited. He quotes from the report of Dr. Oldham, and gives a section of the coal seam and associated rocks at the point referred to above, *viz.*,

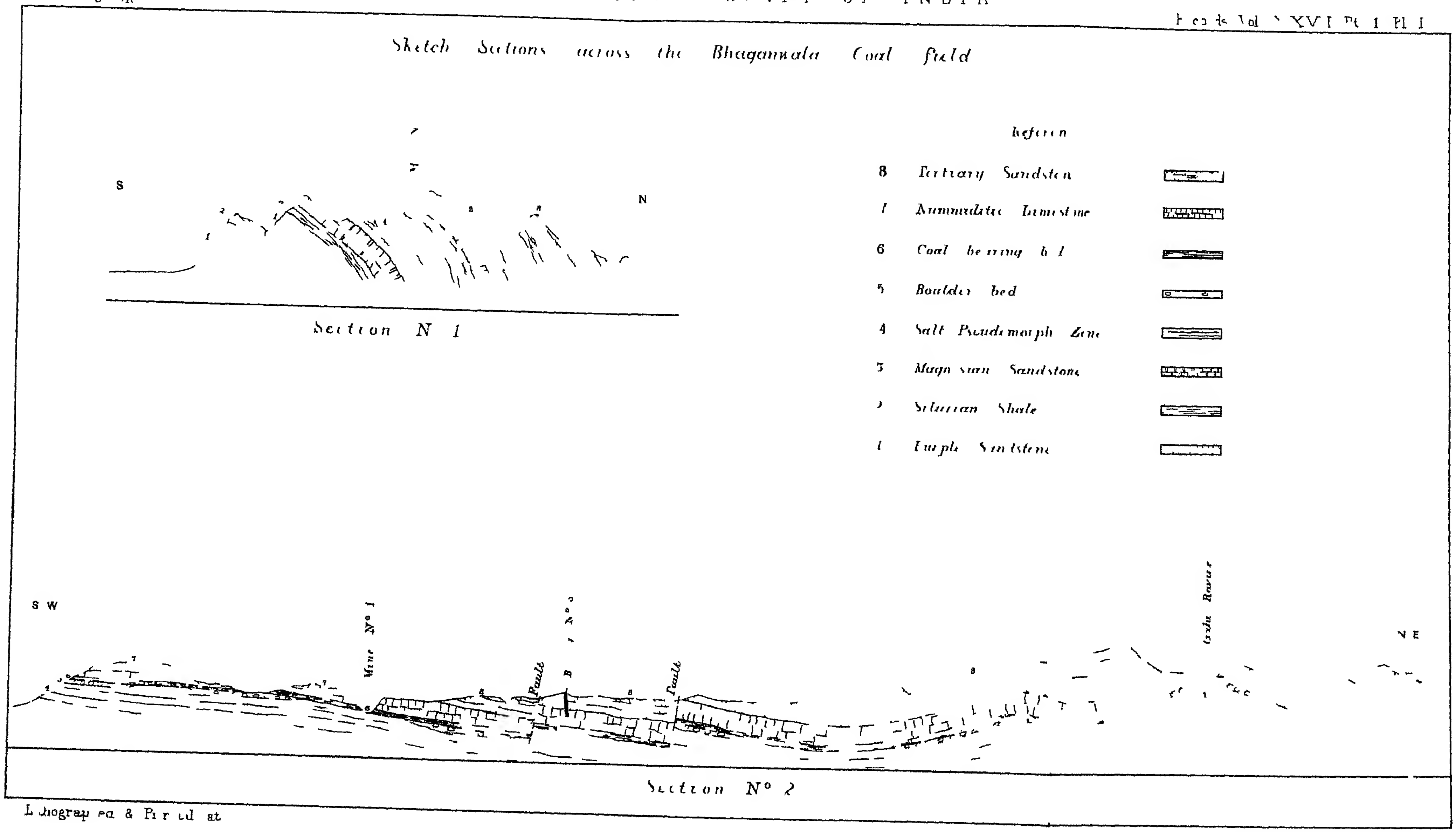
[1] Memoirs, G. S. I., Vol. XIV.


T D La Touche
GEOLOGICAL SURVEY OF INDIA.
Records Vol XXVII Pt 1
PLAN OF THE
BHAGANWALA COAL FIELD
SALT RANGE PUNJAB.
Surveyed and drawn by
W. B. Dallas Edwards Asst. Superintendent
Tom D La Touche
Deputy Superintendent in charge
Season 1892–93
Scale 5" = 1 Mile
INDEX
Alluvium
Tertiary Sandstone
Nummulitic Limestone
Coal-bearing bed
Boulder bed
Salt Pseudomorph Zone
Magnesian Sandstone
Dips
Paths
ARA PLAIN
ARA
GUJRA
AMLA
DHAMIALA
CHATIAN
Garden and Well
Boring No 2
Boring No 3
Slopes cut up by ravines and covered with Scrub Jungle
Bhaganwala Fort
Horizontal Section No 1
Geological Survey Office

To face

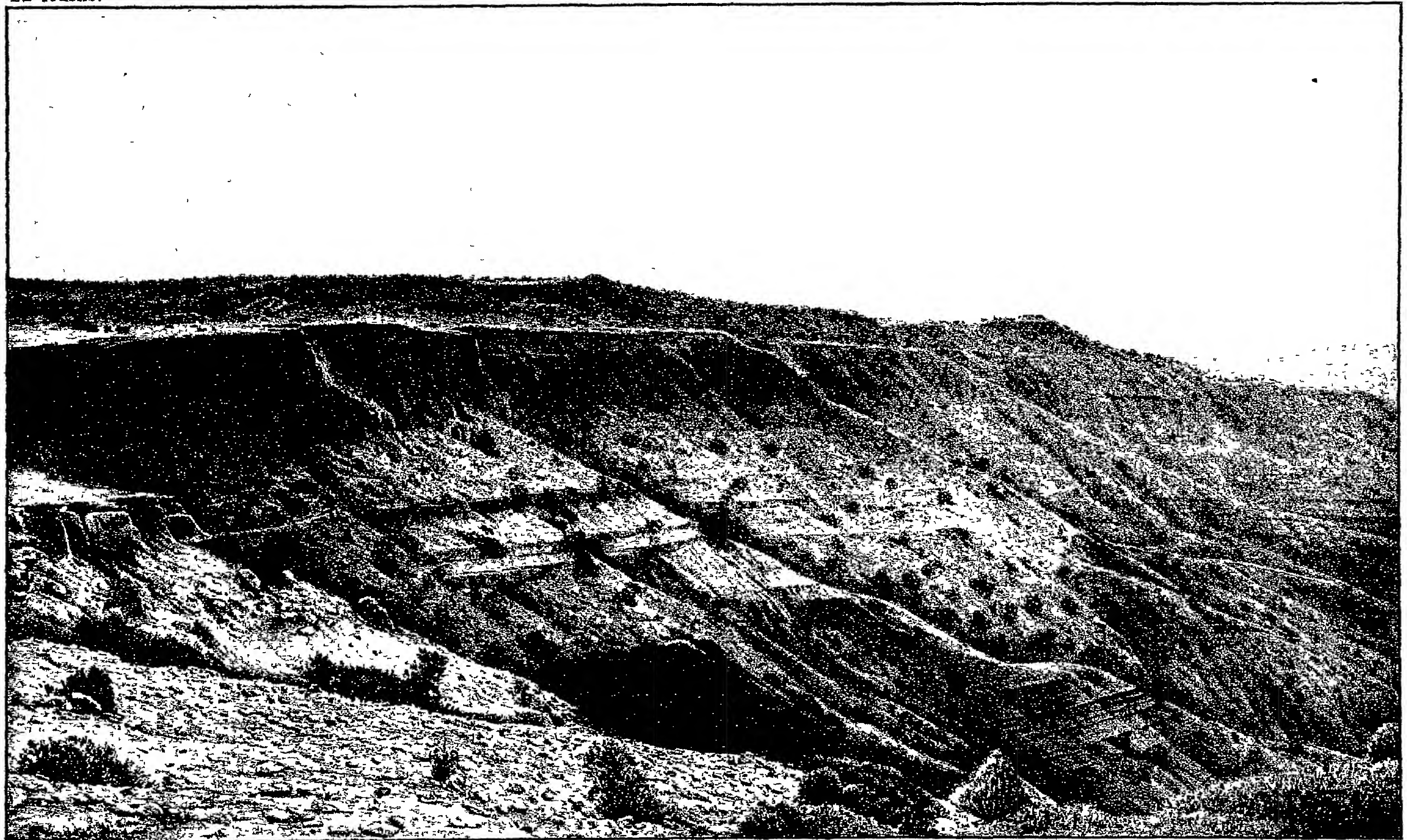
GEOLOGICAL SURVEY OF INDIA

Records Vol. XVI Pt. 1 Pl. I



Lithographed & Printed at

Geological Survey Office



Lithographed & Printed at Geological Survey Office

Scarp above Mine N° 7 —— Bhagavada Coal-field

where the beds lie at a considerable angle.[1] He does not seem to have been acquainted with the coal at the other point where it is now being worked, at mine No. 7, where the beds are almost horizontal, though both he and Dr. Oldham state that the outcrop may be traced for 2 miles. Probably the outcrop of this good coal at No. 7 was at that time concealed by talus.

Since the publication of Mr. Wynne's Memoir in 1878, nothing appears to have been done to prove the capabilities of the field for many years, except that a number of holes were dug into the outcrop by native contractors, who of course took the coal wherever it was most easily to be got, without any regard for the future, and if they had been allowed to continue in that fashion, might in time have done irreparable damage. Some 2,000 tons is said to have been removed in this way. But in 1892 Mr. Luckstedt, Executive Engineer, Manager of the Dandot Colliery, submitted a report, in which the total quantity of coal was estimated at 10 million tons, and of this 6 millions were said to be available. This estimate was so largely in excess of that made by Dr. Oldham, and, as pointed out by Dr. King, Director, Geological Survey, rested upon such slender evidence, that it was felt advisable, before sanctioning the expense necessary to provide better communication with the railway than the present system of pack animals, that some further evidence should be collected, if possible, supplemented by borings, to prove the existence of coal or otherwise at points where it could not be reached by drifts from the outcrop. Accordingly, the present detailed survey of the field was undertaken. While it was in progress Mr. Luckstedt furnished another report, in which the total amount of coal is estimated at 20 millions of tons. This report will be discussed further on.

Plan of the coal-field.

The best available map of the district, on the scale of 1 inch = 1 mile, not being sufficiently detailed to allow of geological boundaries, outcrops, etc., being laid down upon it with accuracy, a large-scale plan of the field was prepared by Mr. Dallas Edwards, Assistant Superintendent, Geological Survey, during the past working season. A reduced copy of the plan, which was surveyed on a scale of 6 inches = 1 mile, is attached to this report. The advantages of making such a plan as this at the same time that the geological survey is being carried on are obvious. The boundaries of the different formations and other geological features can be inserted on the plane table, as the survey proceeds, with an accuracy not obtainable when an enlargement from a small-scale map, made without any reference to geological details, is the only one available.

Geological structure. (See Sections 1 and 2, plate I.)

The geological structure of the rocks is not very easy to describe, as the forces which have determined it appear to have acted from two or more directions, whether simultaneously or at different periods, and the result is somewhat complicated. At the eastern end of the field the rocks are tilted up at a high angle, apparently forming the northern limb of a great anticlinal, the southern limb and crown of which have been removed by denudation. As we proceed westwards the anticlinal becomes broader and flattened, as it were, spreading out into a series of gently undulatings, anticlinals and synclinals, which occupy the space between the highly inclined rocks at the southern edge of the range and the northern edge of the coal-field. Great

[1] Memoirs, G. S. I, Vol XIV, Pt. XIV, p. 138.

denudation has taken place, so that a deep gap has been formed between what is now the southern edge of the coal-field and the edge of the hills, a large area of what may have been productive coal-bearing beds having been removed. Although the rocks are seldom quite horizontal over that part of the field which has escaped denudation, yet they dip either to the north or south at very low angles, having generally sufficient inclination to render drainage of the mines, when it shall be necessary, a matter of little difficulty.

Faults.

Faults are neither numerous nor of great extent in this field. Such as do occur are marked on the plan, and it will be seen that they nearly all run in a northerly direction, starting from the southern scarp, and soon die out, so far as can be seen, on the surface of the plateau. The longest can be traced for about 1,500 yards from the edge of the scarp, near and to the east of the Railway bungalow, and appears to have a throw of about 50 feet at most. This and some of the others appear rather to be very sharp folds accompanied by faulting, than ordinary faults, but the result is the same, so far as the relative position of the beds on either side of them is concerned.

Formations represented.

The formations which we have to deal with are very few in number, since the coal occurs at only one well-defined horizon, and the rocks below that horizon need not be noticed. A general vertical section through the beds shown on the plan is given below :—

In descending order,

	Maximum thickness. Feet.	Inches.
Nahan sandstones and clays, thickness variable, sometimes absent	...	...
Nummulitic limestone	160	0
Yellow and dark grey shales	14	0
Coal	7	0
White sandstone with pebble bands	50	0
Olive shales and clays with boulders of crystalline rocks . .	20	0
Salt pseudomorph zone, red and grey shales	...	...

Nahan sandstones.

Only the lowest beds of this formation are represented in the coal-field. They consist of soft grey sandstones interstratified with red or purple shales and clays, and with irregular pebbly bands from 1 to 8 feet or so in thickness. The composition of the beds varies horizontally a good deal, so that the section passed through in a boring at one point may be very different from that at another. The lowest beds contain pieces of silicified wood, also fragmentary bones and teeth, mixed with pebbles of quartzite and other crystalline rocks. They also contain what appear to be pebbles of the underlying limestone, but the latter is very nodular, and these apparent pebbles may be merely nodules mixed with the sandstone while it was still soft and not really rolled pebbles. No sign of unconformity can be detected between the sandstones and underlying rock. The sandstones have been greatly denuded within the limits of the field, and often removed entirely, patches remaining here and there as outliers, but to the north-east of the Ara plain these patches coalesce, increasing to a thickness of several hundred feet, so that the underlying rocks are only exposed where deep ravines have cut through the whole series.

Nummulitic limestone.

The scarped outcrops of limestone which form such a conspicuous feature in the Salt-Range are of considerable importance as a guide to the position in which indications of coal should be looked for, because the limestone everywhere overlies the coal-bearing bed, and it is, indeed, to the softness of the latter, coming immediately beneath the hard limestone bands, that the aforesaid scarps are due. As represented in this coal-field the limestone has lost much of the thickness and solidity which it displays further to the west, as at Dandot, and even within the limits of the field its thickness diminishes from about 160 feet on the west to less than 50 feet on the east, while beyond the limits of the plan it thins out entirely within no great distance, if traced along the outcrop.

A section of the limestone at mine No. 12 gives, in descending order:—

		Feet.	Inches.
Nodular limestone	about	20	0
Solid and very hard limestone	„	15	0
Nodular limestone with partings of shale and clay	„	25	0
Solid hard limestone	„	6	0
Nodular limestone with partings of clay	„	10	0
Nodular limestone with bands of shale and clay	„	36	0
Solid and very hard limestone	„	7	0
Nodular limestone	„	26	0
Nodular limestone with partings of clay and shale	„	14	0
Shaly limestone	..	5	0
TOTAL		164	0

The want of homogeneity in the limestone has been found to be a serious drawback in the attempts made to bore through it, at any rate with the steam boring machine, for though the tool cuts through the hard bands readily enough on reaching the soft clays and shales it becomes clogged, and even if any progress is made, fragments of the shale frequently fall from the sides of the hole, and cause the tools to become jammed, a difficulty that it has not yet been found possible to surmount.

Coal-bearing beds.

Immediately underlying the limestone are found the coal-bearing beds, consisting of dark-bluish grey shales passing down into carbonaceous shales or sandstones and coal. The maximum thickness of the shales is not more than 14 feet, and it is often less, a circumstance which is greatly in favour of mining operations here as compared with Dandot, where the shales above the coal reach a thickness of 40 feet. Another advantage here is that a band of hard sandstone is frequently found between the coal seam and the shales, affording a good roof to the workings. Beneath the coal-bearing beds is a strong band of white sandstone, often stained yellow or brown by oxide of iron. This also frequently contains strings of carbonaceous matter, and sometimes pebbles and boulders of crystalline rocks. Its thickness varies a good deal in different parts of the field.

The rocks which succeed this band need not be described here in detail, as though they afford some interesting points for discussion they have no connection with the subject of this report.

Distribution of the coal.

The evidence so far obtained as to the distribution of the coal in this field is of

two kinds; 1st, that afforded by natural outcrops; and 2nd, that afforded by the drifts and mines which have been put in at numerous points along the outcrop.

1. Outcrop indications.

Beginning at the western end of the long southern scarp, which stretches in an unbroken line for a distance of about 5 miles from mine No. 12 to the east of mine No. 1, the following sections may be observed :—

Section No. I. (see Plan), Mine No. 12—

	Feet.	Inches.
Limestone (see page 18)	about 164	0
Yellow shales	2	0
Dark grey shales	5	0
Carbonaceous sandstone	1	9
Sandstone band	0	6
Coal	1	0
White sandstone	...	...

Proceeding from this point along the left bank of the ravine, the outcrop of the beds beneath the limestone is much concealed by talus, but where visible, the rock is a coarse yellow and white sandstone, the shales apparently being absent; nor is there any trace of carbonaceous matter. Where the outcrop bends sharply to the east, the following section is seen :—

Section No. II—

Limestone	...
Shales	about 3 feet seen.
White sandstone much stained with iron	„ 40 „

No good section of the rocks between the limestone and sandstone is exposed along this part of the scarp up to drift No. 9, but where the shales are visible they are not carbonaceous.

Section No. III Drift No. 9—

	Feet.	Inches.
Limestone.	...	...
Carbonaceous shale	5	0
White sandstone	54	0
Pink sandstone	18	0
Grey shales	...	...

Again, between this and drift No. 8, there is much talus, but a clear section is exposed at the mouth of the latter drift beneath the bungalow, and close to the road from Ara to Bhaganwala.

Drift No. 8—

	Feet.	Inches.
Limestone	...	...
Shales	about 4	0
Carbonaceous shale	1	0
White sandstone very much stained at top	...	...

To the east of the road a little carbonaceous shale shows at intervals, but no good sections are exposed till near drift No. 7 A. In a gully about 500 feet west of this drift the section is—

Section No. IV—

	Feet.	Inches.
Limestone	...	...
Shales	10	0
Ferruginous sandstone	0	6
Slightly carbonaceous sandstone and shale	1	0
White sandstone	...	...

At about 75 feet to the west of the drift the coaly stuff has increased to 2 feet 4 inches, and at the mouth of the drift the section is—

Drift No. 7 A—

		Feet.	Inches.
Limestone		...	...
Sandy marl with many bivalves		1	4
Yellow shale		3	0
Dark grey shale		7	0
Sandstone	about	0	6
Carbonaceous shale and *coal*		2	0
White sandstone		...	...

Beyond the drift the carbonaceous band dies out again, being about 1 foot 6 inches thick at 100 yards from it. The ground is then again covered by talus, and no good sections are seen until the spur overlooking mine No. 7 is reached. From this point to mine No. 6, a distance of about a mile and a quarter, clear sections are freely exposed. A photograph of this portion of the scarp is attached, (Plate II) which gives a good idea of its general aspect. No coal or indications of it are seen, however, until a point is reached about 300 yards west of mine No. 7, where about 2 feet of carbonaceous sandstone appears at the base of the shales beneath the limestone (Section No. V). This band of carbonaceous sandstone gradually increases in thickness, and the proportion of coal it contains becomes more considerable up to mine No. 7, where the section is—

Mine No. 7—

		Feet.	Inches.
Limestone	about	100	0
Shale		11	0
Sandstone band		0	7
Coal		5	3
White sandstone		...	...

To the east of the mine the coal thins out again, until at about 200 yards distance the seam is represented by a band of grey sandstone with strings and nests of coal. Beyond this there are no signs of coal, or only very slight indications, for a considerable distance, to near drift No. 6 B. Here there is another lenticular band of coaly shales and sandstone. Where first seen, the coaly layer is 1 foot 3 inches thick, increasing to 2 feet 9 inches at about 12 yards further on, and continues with about the same thickness, but very irregular, to some 50 yards beyond the drift. Talus then covers the outcrop to near mine No. 6.*

At the mouth of mine No. 6 the section is—

	Feet.	Inches.
Limestone	...	...
Shale and clay	8	0
Coarse sandstone with nests of *coal*	1	0
Sandy coal	4	0
White sandstone	...	...

* Mr. Luckstedt in his second reportspeaks of a "line of erosion" about 1,200 feet wide as occurring in the scarp between mines Nos. 7 and 6, but I could not detect anything of the kind, nor could I see the "false bedding" he mentions in the lowest portion of the nummulitic limestone, though I looked for it carefully, as such a structure in the limestone, considering the mode of origin of the latter, would be worth studying.

Beyond this again the rocks are hidden by talus, but at 450 yards from the mine a section is exposed—

Section No. VI—

	Feet.	Inches.
Limestone	...	...
Brown clay	3	0
Soft sandstone with strings of *coal*	1	0
Hard sandstone	1	2
Soft sandstone, slightly carbonaceous	0	10
White sandstone	...	...

A little further on the whole of the rocks are concealed beneath a great slip, which has covered the hill-side with a confused mass of blocks of the Nahan sandstone from above. Where they appear again to the east of the slip no indications of coal are seen up to and upon the col dividing the drainage towards Bhaganwala from that into the Bunhar river; but they appear again near the head of the ravine on the east. At first there are two bands of coaly stuff from 10 inches to 1 foot thick, separated by sandstone. The shales above the coaly band are of a bright red colour, as though they had been burnt. Continuing along the side of the ravine the rocks are somewhat concealed by talus. Occasional indications of coal are seen as at section No. VII, where there are 15 inches of sandy carbonaceous clay, but sometimes the place of the seam is taken by a pebbly band of sandstone. It then begins to thicken gradually to about 3 feet at mine No. 5. Here the rocks begin to bend over with a dip of about 30° to the north. The seam may be traced continuously, and at the same time improving in quality, beyond mine No. 4, where the thickness is 3 feet 2 inches, down to the bottom of the ravine. At this point the section is—

Mine No. 3 W—

		Feet.	Inches.
Base of Nahans	Soft grey sandstones, weathering red	...	...
	Light green and brown marly clay, with nodules of limestone	3	0
Limestone, very nodular, with partings of clay		50	0
Limestone with small nodules		9	0
Shelly bed		4	6
Sandy limestone		1	0
Yellow marly bed with selenite in cracks		1	0
Coal		7	0
Sandstone		21	0
Clays, light green		10	0
Green shales with much selenite		13	0
Red shales		...	

Dip N. 10° E. at about 50°.

The coal seam continues up the hill-side to the south with an average thickness of about 4 feet and down to the ravine in which mine No. 1 is situated. At the bottom of this ravine the section is—

Mine No. 1—

	Feet.	Inches.
Nahan sandstone	...	...
Limestone	20	0
Purple shale	2	0
Dark-coloured sandstone	6	0
Coal	4	6
Sandstone	16	0
Green clays and shales	10	0
Red shales	...	...

Half-way up the hill on the south bank of this ravine a trial drift has been put in, but without finding coal. The section at the mouth of the drift is—

Section No. VIII—

	Feet.	Inches.
Limestone	18	0
Purple clay	2	0
Dark-grey and white sandstone	8	0
Slightly carbonaceous sandstone	2	0
Carbonaceous sandstone	3	3
White sandstone	8	0
Greenish clays and shales	15	0
Red shales	...	...

At the top of the hill, the furthest easterly point shown on the plan, all traces of coal have disappeared. It will be noticed that the limestone is very much attenuated in these latter sections, as compared with its thickness at the western end of the field, and at a short distance further east it thins out entirely.

Section No. IX—

	Feet.	Inches.
Grey Nahan sandstone	...	...
White nodular limestone	2	0
Yellow limestone, very fossiliferous	14	0
Purple shale with a band of clay at top	2	0
White sandstone	10	0
Red shales	...	...

Besides this long line of outcrop along the southern edge of the field, the drainage from the plateau has in more than one place cut through the formations above the coal-bearing beds, and we are thus enabled to form an opinion as to how far the coal seam extends to the north and east. The ravines in which the beds are thus exposed are the Rai ravine, to the east of Ara village, the Gahi ravine running east from the village of Dhamiala, and the Sikki ravine, which extends along the northern edge of the field.

Rai ravine.

In the Rai ravine the rocks beneath the Nahan sandstones are exposed over a considerable area as an inlier, the outcrop of the coal-bearing beds forming a narrow, continuous band on both sides of the ravine. Several good sections are exposed, especially on the north bank, but on that side there are no indications of coal whatever, the place of the coal seam being taken by shales. On the south bank a section at the mouth of Drift No. 10 gives :—

	Feet.	Inches.
Limestone	...	...
Grey shales	4	0
Ferruginous conglomerate mixed with clay, containing quartz pebbles	2	0
White sandstone with strings of *coal* and coaly stuff lining cracks	8	0
Fine yellow sandstone with pebbles	3	0

At the mouth of the drift some distance further to the east, marked Geological Survey Drift on the plan, which I had put in at this point because it was opposite to mine No. 7 on the southern outcrop, and it was important to discover how far the good coal in that mine extends in a northerly direction, the section is—

	Feet.	Inches.
Limestone	...	...
Shales	about 10	0
Yellow sandstone	1	6
Carbonaceous sandy shale	1	0
White sandstone	...	...

There is no "seam of weathered coal, 18 inches thick," here, as stated by Mr.

Luckstedt, but, as is so often the case in this field, the sandstone which occupies the place of the coal is irregularly carbonaceous.

In the bottom of the ravine, where the rocks dip below the level of the stream bed, at drift No. 11, there is no good section to be seen, both banks being more or less covered by talus, but just within the mouth of the drift there are about 3 feet of shale at the base of the limestone, overlying sandstone, in which there are no traces of coal.

Gahi ravine.

In the Gahi ravine also a small closed area of the rocks beneath the limestone is exposed, but with the same disappointing results, as regards indications of coal, as in the Rai ravine. At only one point could I find any traces of carbonaceous matter, and I had a cutting made here as the outcrop was obscured by talus. At a distance of 30 feet in, this gives the following section:—

Section No. XI—

	Feet.	Inches.
Limestone	...	...
Yellow shale	2	0
Slightly carbonaceous sandy band, very irregular	0	6
Soft white sandstone and clay	1	6
Dark-grey shales	...	...

Wherever at other places in this ravine the rocks between the limestone and the greenish-grey shales of the boulder bed are exposed, they consist of yellow and pink sandstones, even the shales which usually occur at this horizon being absent.

Sikki ravine.

Along the southern bank of the Sikki ravine the outcrop is exposed for more than a mile, but that of the coal-bearing beds is generally concealed by talus from the limestone above. At one point there are some indications of coal, and here a drift (No. 14) has been put in The section at its mouth is—

Drift No. 14—

	Feet.	Inches.
Limestone	...	...
Marl	2	0
Carbonaceous sandstone	4	6
White sandstone	6	0
Boulder bed	...	...

Further to the west, near the village of Sikki, the following section was measured:—

Section No. X—

	Feet.	Inches.
Limestone	...	...
Shales	4	0
Ferruginous sandstone	2	6
Concealed by talus	6	0
Soft purple sandstone	3	0
Pebbly band	4	6
Yellow sandstone	8	0
Boulder bed	...	...

Conclusions to be drawn from evidence afforded by outcrops.

In considering the evidence afforded by the natural outcrops of the beds, as detailed above, it must be borne in mind that, although the outcrop is to a great extent concealed by talus, and the evidence is therefore to a similar extent imperfect, yet it is seldom that an interval of more than a few hundred feet of talus-covered ground separates points at which the beds are more or less well exposed, in the numerous

small gullies which furrow the sides of the scarps. Therefore the cumulative evidence derived from such a large number of sections becomes more worthy of acceptance. Moreover, in those cases where good coal does occur, as at mines Nos. 7 and 1 to 3 W, it shows distinctly at the outcrop, and the seam may be traced almost continuously on either side of the points of greatest development, gradually thinning out as we recede from those points, until at last it disappears entirely, or is replaced by coaly stuff imbedded in sandstones or shales. Thus we are justified in drawing this conclusion from a study of the outcrops alone, that the distribution of coal is extremely irregular, and that it would be very unsafe to form an estimate of the quantity of coal that may exist within the area under consideration, from such evidence, taken by itself.

Evidence afforded by the drifts.

The drifts that have been put in at various points along the outcrops may be conveniently divided into two groups, *viz.*, those situated in the narrow neck of coal-bearing rocks at the eastern end of the field, from No. 1 to No. 7, including the drifts in the Rai ravine, and those situated in the western portion of the plateau, Nos. 7 A to 12 on the southern outcrop, and No. 14 in the Sikki ravine on the north.

Drifts in eastern portion of coal-field.

Taking first those in the eastern portion of the field, it should be noted that these are the only places from which coal of good quality has yet been procured. Drifts Nos. 1 to 5 are all on a continuous band or seam of coal, which may be traced, as above described in treating of the outcrops, for a distance of nearly a mile along the strike of the beds, and having an average thickness of about 4 feet. Nos. 1 and 3 E are driven from either side of a ridge, and meet in the middle of it, having a total length of 1,380 feet. The centre pit No. 2, driven from the highest point of the same ridge down the dip of the beds, meets the other two about half-way through the ridge, and continues beyond them to a distance of over 300 feet from the outcrop. Thus the continuity of the seam in this area has been fairly well proved. The thickness varies from 3 feet 9 inches to 7 feet, and 5 feet may be taken as a fair average.

No. 3 W is driven along the strike of the beds on the bank of the ravine opposite No. 3 E, to a distance of about 300 feet from the outcrop, and shows the seam reduced in thickness from 3 feet 6 inches at the outcrop to 2 feet 9 inches at the farthest point reached. A branch drift is also being put in at right angles to this in the direction of the dip, but it has not proceeded far, having been stopped for the present by water. Three feet may be taken as an average thickness for the coal affected by this drift.

Nos. 4 and 5 were driven to a distance of only 100 feet from the outcrop, and I have no information regarding them.

Drift No. 6 starts in about 4 feet of coaly sandstone, in which the coal and sandstone are disposed in thin, alternate layers. Further in the seam becomes thinner, but of better quality, and at 240 feet from the outcrop there are 2 feet 4 inches of good coal.

Between this and drift No. 7 one or two drifts have been put in at points where there are indications of coal, but they are now blocked up, and I have no information regarding them.

Drift No. 7 was started in good coal, about 5 feet thick at the outcrop, and

extends in a northerly direction for about 500 feet, still in good coal of the same thickness. It has been opened out as a mine, and a considerable amount of coal has been worked out from either side of the main drift. The seam varies in thickness from 2 feet 9 inches on the west side of the main drift to between 4 and 5 feet on the east, and a thickness of 4 feet 6 inches may be taken as an average throughout the area proved by it.

In the Rai ravine three drifts have been put in, all on the southern bank. Of these No. 10 extends to a distance of 180 feet from the outcrop, in the shales below the limestone, but without finding any traces of coal. No. 11 is driven at the lower end of the ravine, where the rocks are brought down by a dip of about 20° to the level of the bottom of the valley. It extends to about 170 feet from the outcrop, and shows about 3 feet of shale underlaid by sandstone, in which there are occasional strings of coal, but no coal is found in the shales.

In the drift between these, which I had put in at this point as being opposite to mine No. 7, and which extends to about 200 feet from the outcrop, a similar section is shown, there being some 10 feet of shales beneath the limestone, without a trace of coal, underlaid by sandstone in which strings of bright coal, up to an inch or so thick, are occasionally found. And it is evident that the seam of good coal 5 feet thick, in mine No. 7, must die out in this direction, as it does along the outcrops on either side of that mine. Mr. Luckstedt, it is true, asserts that there is no prospect of reaching the coal of mine No. 7 within a distance of 400 or 500 feet from the outcrop in the Rai ravine, as, according to him, the whole of the southern side of the ravine is a slipped mass. But, apart from the fact that there is no evidence of such a general slip at that distance from the outcrop, even if it had occurred, it is inconceivable that it should have utterly destroyed the coal, and left the soft shales, in which the coal should be found, intact. In this drift there is a small fault or hitch at 110 feet from the mouth, bringing down the limestone, but the section is not affected by it; and the drift has been continued far beyond it, without meeting with any improvement. At drift No. 11 there is certainly no question of a slip, as the beds dip below the level at which denudation can have affected them, and are in an exactly similar position to that which they occupy further along the strike, at mine No. 3 W; and there is no reason whatever why the coal, if it originally existed at both these points, should have disappeared at one of them and remain at the other. These drifts, in my opinion, prove conclusively that the coal does not extend continuously from the southern outcrop to the Rai ravine, but thins out somewhere in the interval; and so far from agreeing with Mr. Luckstedt, I say that we have as yet no evidence, and there is no reason for thinking that the seam extends even to within 500 feet of the mouths of drifts in that ravine.

Drifts in the plateau.

Drift No. 7 A shows near the outcrop a thickness of 2 feet 7 inches of sandy coal, *i.e.*, a band consisting of thin alternating layers of bright coal and sandstone. At 70 feet in this dwindles to about a foot of the same stuff, then thickens again to 3 feet at the end of the drift, 200 feet from the outcrop.

Drift No. 8 is now closed, but Mr. Luckstedt states that it extends for 120 feet from the outcrop, and that the 1 foot of carbonaceous sandstone exposed at the mouth does not improve further in. He accounts for this by saying that a fault

runs about 300 feet to the east of the drift in a northerly direction. The fault is certainly there, but I do not see how it could have affected the thickness of the coal, supposing that it was originally greater at this point. Faults are of common occurrence in most coal-fields, but beyond altering the relative positions of the seam on either side of them, they have little or no effect on the thickness of the coal, except along the actual plane of dislocation, where the rocks are sometimes crushed, and I know of no instance where a seam has been affected in such a manner, at so great a distance as 300 feet from the fault, as to reduce its thickness to such an extent as Mr. Luckstedt imagines.

Drift No. 9 is also now stopped up, but was apparently no more promising than No. 8.

Considerable importance must be attached to the indications afforded by mine No. 12, for assuming for a moment that Mr. Luckstedt is correct in attributing the general absence of signs of a thick seam of coal along the outcrop to slipping and other dislocations of the strata, this is just the place where we ought to find that thick seam in full force. For at this spot, not only is the scarp of recent formation lying as it does close to the head of a small ravine in which there is a perennially flowing stream of water, but there are no slips or faults anywhere in the vicinity, by which on his hypothesis the seam, supposing it had originally existed, could have been destroyed. Yet, on the one hand, in spite of the freshness of the outcrop, no thick seam of good coal shows in it, and on the other, although the drift has been pushed to a distance of over 250 feet from the outcrop, nothing like a continuous seam of good coal has been met with. The place of the seam is occupied by a band of carbonaceous sandstone and shale, varying in thickness from 1 foot 7 inches to about 4 feet. The sandstones usally contain thin strings of coal of good quality, sometimes thickening to a band about a foot thick, but useless as fuel, from the amount of foreign matter inseparable from it. Some of the so-called coal from this mine was tried in the engine of the steam boring machine, but it would not keep alight in the furnace.

The same remarks apply to the only drift that has been put in on the northern side of the field, No. 14. Here also the scarp above the outcrop is not very high, and there are no signs of slipping or other dislocations anywhere near the drift. It extends to a distance of about 200 feet from the outcrop, always in carbonaceous sandstone with the strings of bright coal which are such a common feature in the sandstones that so frequently occupy the place of the coal seam in this field.

It may be objected that the non-occurrence of good coal in these two drifts may be a mere accident, owing to an unfortunate choice of position, but seeing that both of them were put in where they are solely because of the comparatively promising indications of coal at the outcrop, that argument can hardly be considered as valid.

If these two drifts, in conjunction with No. 7 A, 8, and 9, prove anything at all, they prove that a continuous seam of coal, 3 or 4 feet in thickness, does not underlie the whole of the plateau,—that is, over by far the greater part of the area coloured as productive of coal on Mr. Luckstedt's maps; and the conclusion drawn from the evidence afforded by the outcrops,—*viz.*, that the distribution of coal is extremely irregular—is thus quite borne out by that of the drifts. Still, however, it is quite possible that coal in large quantities may exist beneath the

plateau, but until its existence has been proved, it is quite out of the question to take such hypothetical coal into calculation, when speculating upon the total quantity obtainable from the field.

I may mention here that my colleague Mr. Middlemiss, who had been rather sceptical as to whether any correct inferences could be drawn from a study of the outcrops, was convinced after seeing the two drifts, Nos. 12 and 14, of the truth of the conclusions I had come to regarding the irregularity of the coal seam.

Causes of irregularity in distribution of coal.

This irregularity in the distribution of the coal may be due to either of two causes,—*viz.*, either that the coal was originally deposited in limited areas, or that subsequently to the deposition of the coal bed over the whole area it was irregularly denuded. From the manner in which the seam, wherever there is good coal, can be seen passing horizontally into carbonaceous shales and sandstones, I am inclined to think that the first of these causes is sufficient to account for the facts, and that the coal was formed in detached pools or marshes of limited extent, the banks of which are represented by the barren ground intervening between the different productive areas. I have, moreover, not been able to find any good evidence of erosion subsequent to the deposition of the coal, except that in some cases the sandstones overlying it contain what appear to be fragments of coal; and as the period following that in which the coal was formed seems to have been one of rather rapid depression, as evidenced by the appearance of the limestone at no great distance vertically above the coal horizon, it is likely that the beds were quickly covered by shales and sandstone, and were thus protected from denudation.

Age of the coal.

A few obscure casts of fossils, principally gasteropods, have been found in the sandstone layers immediately above the coal at mine No. 7, not sufficiently well preserved to determine the age of the beds, but there can be little doubt that they belong to the nummulitic group. It is remarkable, however, that the coal frequently contains specks and nests of fossil resin, which is characteristic of the coals of cretaceous age in Assam, and in that part of the country serves to distinguish them from the newer tertiary coals.

Borings.

Before the present investigation was undertaken, it was pointed out by the Director of the Geological Survey that borings would have to be put down on the plateau, to prove the existence or otherwise of coal beneath it; and all that I have seen of the conditions under which the coal occurs has convinced me that several borings should be made. The distance to be sunk in any borings made on the plateau need not be more than 300 feet or so, and at many points would be much less, whereas if it is proposed to continue driving from the outcrop until the plateau is thoroughly proved, many thousands of feet of barren rock may have to be passed through, before any coal is struck; and on the score of expense alone it seems to me that a serious effort should be made to carry out those borings at any rate which have been started during the past six months, down to the coal horizon. Two of these were partly sunk with the aid of the steam boring machine belonging to the Geological Survey, which does its work excellently so long as hard and homogeneous rocks have to be passed through, the average rate of progress being about 3 feet per hour in the sandstone, and over 1 foot per hour in the hard limestone. But the latter contains bands of soft shale and clay, which it has been hitherto found impossible to bore

through with the machine. These borings are being proceeded with by hand, as the soft beds present no obstacle to that method, but in the harder limestone bands progress is extremely slow. A third boring is being sunk by the aid of the machine, and so far has proceeded satisfactorily, but it remains to be seen whether similar soft bands will be met with, as in the other two borings.*

Quantity of coal available.

In making an estimate of the quantity of coal obtainable from the Bhaganwala field, the foregoing considerations will have shown that we are justified in taking into account only those areas in which the existence of workable coal has been actually proved, and it will be noticed that these are just the areas in which good coal appears at the outcrop, *viz.*, along the scarp from mines Nos. 1 to 5, at No. 6, and No. 7. In no other instance has any of the drifts proved the existence of good coal, nor have the indications of its presence at the outcrop been found to improve further in. As far as regards the areas above referred to, I have satisfied myself that Mr. Luckstedt's figures, as given in his second report, are reliable, and I calculate the available quantity of coal as follows:—

(*i*) Mines Nos. 1, 2, and 3 E.

These may be taken together, as they are practically one and the same mine.

Estimated average thickness of seam . = 5 feet.
Area actually proved . . . . . = 384,000 square feet.

$$\text{Quantity of coal} = \frac{384{,}000 \times 5}{30} = 64{,}000 \text{ tons.}$$

To this may be added, according to the depth, measured along the dip, to which the mines can be worked, for each 60 feet in that direction, or an addition of 96,000 square feet to the area,

$$\frac{96{,}000 \times 5}{30} = 16{,}000 \text{ tons.}$$

Supposing, for instance, that it is found feasible to work the mine to a depth of about 2,000 feet along the dip, below the bottom of the ravines on either side. And I think that such a depth would be quite practicable, for it is not likely that any great influx of water would be met with, considering the climate of the locality.

* Since the above was written, this boring, No. 4 on the plan, was stopped, as far as the machine was concerned, by a soft layer in the limestone at a depth of 150 feet from the surface. About 45 feet of the limestone had then been bored through, and I calculated that about 70 feet more remained before the coal-bearing bed would be reached. Should it be found impossible to carry any of these borings down to the coal horizon, I recommend that one or more shafts should be sunk, say, close to borings Nos. 3 and 4. These would no doubt cost more than the drifts per foot, but probably not much more, and the distance to be passed through in order to settle the question of the existence of coal beneath the plateau would be so very much less in the case of shafts than in that of drifts from the outcrop, that the cost of the former would be a mere trifle as compared with that of the drifts. Moreover, in case good coal is found beneath the plateau, shafts will have to be sunk in order to ventilate the mines, so that the expenditure on them will not have been wasted.

Assuming, then, that the coal retains its thickness to that depth, we should have a total quantity of about 600,000 tons of coal available from this mine alone.

(ii) Mine No. 3 W—

Estimated average thickness of seam . . . . . =3 feet.
Area actually proved . . . . =64,800 square feet.

Quantity of coal $= \frac{64,800 \times 3}{30} = 6,480$ tons.

It is a question how far the seam extends along the strike beyond the area proved, since where the beds are again exposed in that direction, in the Rai ravine, they contain no coal, but it may be assumed that it continues to at least 1,000 feet from the mouth of the mine. This would give for every 60 feet of depth, measured as before, along the dip, an additional area of 60,000 square feet,

or, $\frac{60,000 \times 3}{30}$ . . . . =6,000 tons of coal.

Assuming, as before, that the coal extends to a depth of 2,000 feet along the dip, and that it can be worked to that depth, this would give a total of 200,000 tons.

Adding the portion which it may be assumed can be worked out along the strike beyond the area actually proved, *i.e.*, over an area of 240,000 square feet, which gives—

$\frac{240,000 \times 3}{30}$ . . . . =24,000 tons

we get a total of about 230,000 tons of coal available from this mine.

(iii) Mines Nos. 4, 5, and 6.

These mines have not yet been opened out sufficiently to furnish any reliable data on which an estimate can be founded; besides which Nos. 4 and 5 are so much closer to what appears to be the original limit of the basin in which the coal was formed, as to render any speculation, regarding the distance to which the coal may extend from the outcrop, extremely hazardous; while No. 6 appears to be in a small detached basin, very little of which has been actually proved to contain good coal.

(iv) Mine No 7—

Estimated average thickness of seam . . . . . =4 feet 6 inches.
Area actually proved . . . . =120,000 square feet.

Quantity of coal proved $= \frac{120,000 \times 9}{30 \times 2}$. . . . . . =18,000 tons.

Here again it is not known how far the seam extends in a northerly direction, as it does not appear in the sections exposed in the Rai ravine, at a distance of 3,750 feet from the mouth of the mine; nor is it known how far it extends laterally on either side of the area proved. Assuming, however, that it extends half-way towards the Rai ravine, with an average breadth of 500 feet, an area of 817,500 square feet will be added to that already proved, which gives—

$\frac{817,500 \times 9}{30 \times 2}$ . . . . . . =122,625 tons.

Adding the amount actually proved, we have in round numbers 140,000 tons available from this mine.

Adding together the whole of these amounts, it appears that 88,480 tons of coal have been actually proved, and that a reasonable estimate of the coal obtainable

from the three mines referred to gives a grand total of 970,000 tons, or, say, one million tons, of coal. From this amount quite 25 per cent. should be deducted to allow for waste, on account of the frequent interbedding of the coal with thin layers of sandstone, and of the remainder a large proportion will be slack coal; but this, it is stated, can be sold at a profit.

General conclusions.

The conditions under which the coal is found, as regards roof and floor, and thickness of the seam, are such that nearly the whole of the amount estimated above should be easy of extraction, under a proper system of mining, and except at the eastern end of the field, and that only when the mining is carried below a certain depth, no pumping will be required to drain the mines. On the whole I consider that though the quantity of coal estimated for is by no means proved, yet there is a reasonable prospect of sufficient coal being obtainable, and under favourable conditions, as to make it quite worth while to improve the existing communications with the railway at Haranpur in the manner detailed in Mr. Luckstedt's reports.

Mr. Luckstedt's reports.

It will be seen from the foregoing that my estimate of the coal available differs considerably from that formed by Mr. Luckstedt, whose estimate amounts to 20 million tons; the reason being that I cannot agree with him in including the very large area coloured as coal-bearing on his map, until some more decided evidence than is at present at our disposal can be brought forward to justify the inclusion of that area. Mr. Luckstedt begins his argument by asserting that "it is a mining axiom that a coal seam cannot abruptly vanish, and that the continuation of a seam that has been worked up to the boundary of a district may be safely assumed." Where Mr. Luckstedt got this "axiom" from I do not know, but from the use of the word "district," I suspect that it refers entirely to the conditions under which seams of coal occur in England, where coal estates are divided into districts, and it may be presumed that where coal has been proved in adjoining estates and districts that it will be continuous between them. But the seams in the coal-fields of this country are not as a rule so continuous in thickness for great distances as they are in the coal-fields of England, and numerous examples might be cited, even in fields of Gondwana age, where the seams do thin out from a workable thickness to one of a few inches or so, if not abruptly, using the word in its strict sense, yet within a few yards. And in fields of nummulitic age, such as this of Bhaganwala, the thinning out of seams, just as they are seen to do here, is the rule rather than the exception. I have seen it in the Jammu coal-field, in those of the Khasia Hills in Assam, and even the enormously thick seams of Upper Assam are not continuous for anything like the distance to which the rocks, in which they occur, extend.

Mr. Luckstedt says again that, if the seams were deposited in detached basins, we should have signs of the approach to the edge of such basins in the appearance of littoral deposits containing pebbles, in line with the coal seams. But it is not at all necessary that such deposits should contain pebbles; in fact, considering the conditions under which the coal was formed, it is hardly likely that pebbles would occur. Their presence would depend on the distance of the nearest hills, in which solid rocks capable of being formed into pebbles occurred, and supposing that the coal was formed under some such conditions as at present exist in Sylhet, and the Sunderbunds, the absence of pebbles is easily accounted for. But the replace-

ment of the coal seam by sandstones and shales, as so frequently happens here, is precisely what we should expect if the coal had been formed under some such conditions as I have supposed, and is in itself an indication that it was laid down in pools or marshes of limited area.

The "axiom" quoted by Mr. Luckstedt is, he says, "based on the laws of sedimentation, by which coal and its associated shales can only be deposited during a prolonged period of great quiescence." However true this may be of the continuous seams to which the "axiom" refers, the facts of the case here seem to point in the opposite direction, *viz.*, that the period of coal formation with which we are dealing was one of rather rapid change. Within a thickness of less than 50 feet of strata, we have several different rock bands, each of which denotes a more or less abrupt change of conditions, and a glance at the sections given above will show that each of these bands varies greatly in thickness at different points. First we have the boulder bed, denoting the presence at no great distance of rocky hills with rapid torrents descending from them; then the white sandstones, showing that the hills were at a greater distance, though the occasional presence of strings and beds of large boulders, imbedded in the sandstone, shows that the area was not beyond the reach of torrents. After this the coal beds and shales, which were probably deposited on a flat plain, far removed from any hills, with frequent depressions or marshy spaces in which an abundant vegetation grew, and traversed by sluggish streams unable to move anything but the finest sand and silt. Lastly, the whole was submerged beneath the waters of the sea, the sudden alteration from shales to limestone showing that the depression was rapid. I can hardly imagine a case in which the evidences of a rapid change of conditions could be more clear.

It would be waste of time to criticise seriously Mr. Luckstedt's geological reasoning, if it were not that its introduction into his reports gives them an air of plausibility, which might impose on those whose acquaintance with geology is slight. To take one or two instances in which his reasoning might be modified by a little more study. He evidently thinks that a "geological basin" has some connection necessarily with the present configuration of the country, as where he says that "the Bhaganwala field lies at the south-west limit of a well-defined geological basin, of which the Salt-Range, the outer Himalayas, the Jhelum and the Indus form the boundaries." These mountains and rivers have nothing to do with the limits of the basin, which, as a matter of fact, extends far beyond them. Then, again, he says, "The (proving of the) existence of coal is a work of purely geological character . . . . To search for coal among rocks the age of which was not known would of course be fruitless." Does he think that it was necessary that the age of the coal measures in Bengal, for instance, should be determined before the existence of coal there was proved, or that three hundred years ago the geological age of the strata about Newcastle and Bristol, from which "sea coal" was sent to London, was known? Or is it possible that he is labouring under the now ancient delusion that all coal seams are of one and the same geological age? Supposing, as might have been the case, that none of the coal seams in Bengal appeared anywhere at the surface, but that the geological age of the rocks had been ascertained by other evidence, that knowledge would of itself have *prevented* any search for coal being made in those rocks. For at the time the Bengal coal-fields were being opened out, no other coal-bearing strata of that particular age were known.

The fact is that geology has nothing to do with the existence of coal at all. There *may* be several millions of tons of coal lying beneath the plateau at Ara_ but if it is not there; no "mining axioms," or geological reasoning, good or bad, will p.. it there. Its existence can only be proved by a rigorous search, and I have already stated my reasons for thinking that this search can best be carried out by me ns of borings or shafts. Mr. Luckstedt, assuming the existence of a 4-feet seam of coal, over the whole area, thinks that borings will be of little use, and, of course, if that assumption were correct, there would be no object in making them, since the depth of the seam from the surface at any point could be calculated from the observed dips, in case it was required to sink shafts for mining purposes.

Finally, supposing that the amount of coal obtainable from the mines at the eastern end of the field is even half only of what I have estimated above, it will take some 20 years, with a regular output of 2,000 tons a month, before it is all worked out; and the expenditure necessary to construct a branch line from Haran_ar would be amply justified. In the meanwhile there is plenty of time to carry out a thorough search on the plateau, and if a large area of coal is found there, the output can be enormously increased, without fear of the coal-field becoming exhausted for many years to come.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 18.—Ending 31st January 1894.

Director's Office, Calcutta, 31st January 1894.

In November last, a slight modification of the disposition list of the Staff became necessary owing to an urgent call for inspection of the collieries in the Salt-Range and at Warora, where the percentage of accidents was considered excessive. The newly-appointed Inspector of Mines for India not having then arrived, it was judged expedient to depute Dr. Noetling for this work, he having had the necessary experience at thin-bedded coal on the Continent. He has reported since on the Dandot and Bhaganwalla Collieries, and is now at Warora.

2. Mr. James Grundy, the Inspector of Mines, reported his arrival at Calcutta on the 14th December, and was placed with the Director of the Geological Survey, through whom he communicates with the Government of India. After some necessary delay in arranging procedure and interviewing the Calcutta Agents of several Mining Concerns, he left early in January, and entered on the examination of the Bengal coal mines.

3. The Director proceeded on tour in Burma on the 28th of December, and returned to headquarters on the 31st of January. He visited the Thingadaw coal-field, and the auriferous tract of Wuntho. At the Thingadaw coal-field, which is worked at present by an incline colliery at Letkobin, the various coal outcrops were

examined under the guidance of Mr. T. H. Ward, the Agent and Manager. There are two kinds of coal which appear to belong to two separate members of the Chindwin series, the lower and better coal occupying a rather restricted area at Letkobin and Kesobin, but the further extensions of this group will have to be explored by boring, primarily between those places and the Irrawaddi bank; while it is not improbable but that larger areas of the same measures may be tapped over a considerable extent of this part of the Irrawaddi tract, though at some depth, as the country is opened up in the progress of coal development. At present, however, progress is considerably handicapped, if not on the eve of being retarded for a time, by the laying down of coal from Bengal in the Rangoon market, the present low price of which would undoubtedly be raised were the Burma development so restricted. In other words, it would almost appear as if a ring had been formed in the Rangoon market to choke off the Burma output of coal, at a price which cannot for long be profitably kept so low as now rules.

4. The Wuntho region is undoubtedly auriferous to a certain extent, having been worked by surface washings in a fitful manner for a long time past, but its development in any such productive way as has lately been prophesied, is entirely dependent on a more prominent occurrence of vein or reef matrix than has been met with so far: the matrix exhibited up to the present time being merely a sporadic occurrence of small and discontinuous strings and narrow ledges of auriferous and pyritous quartz in which there is some free gold, among strongly and deeply weathered schists. Exploration and some prospecting have been made, but these are still only in an initial stage: no large reefs are yet known, and the few indications of increase in the size of the veins met with point to a decrease in their gold-bearing aspect.

5. Just at the close of the last three months, an enquiry which is full of promise of most interesting geological results is being taken up by the Survey in connection with the gigantic landslip which took place in Garhwal last September; and Mr. Holland has been deputed for this work. As yet there is only a demi-official account of the occurrence from the Public Works Department of the North-West Provinces, but it is as well to record now what is known of it from the very interesting memorandum given by Colonel R. R. Pulford, R.E., Superintending Engineer 2nd Circle, Provincial Works, Lucknow, who visited the scene of what he has designated as the "Gohna Slip."

6. It appears that the site of this *debacle* is up the valley of the Bihri Ganga, a tributary of the Alaknanda, some 80 miles over mountain and valley, due north of Naini Tal. The bed of the river is about 5,000 feet, and the hill on the right bank, from which the mass fell, has a height of about 9,000 feet above sea-level. On the 22nd of September, a tremendous mass of rock material was detached, leaving an almost perpendicular section of hill face 4,000 feet high. The force of the fall carried the rocks and *débris* from the right bank, right across the valley of the river and half-way up the steeply scarped hill on the left bank; after which the mass settled down again in the river bed forming a dam with a big slope up against the hill on the left bank; the consequence being that there is now an appearance as if a portion of the dam had been formed by a big slip from the steeply scarped hill of this side of the valley also. Further slips which took place during heavy rain in October have piled up the dam on the right bank against the hill on that side, so that the top of the dam has a large depression in the centre

some 150 feet or more, between two sloping mounds of rocks and smaller *débris*. The dam itself is a very massive affair, being largely composed of enormous masses of rock, some of which are calculated to be more than a thousand tons in weight. There is, in addition, a very large admixture of smaller detritus and broken rock, and a thick layer of impalpable powder which gives the whole place the character of being covered with white clay dust, which Colonel Pulford likens to the country about Vesuvius after an eruption. The dam may be taken roughly to be 900 feet high, 2,000 feet broad at the top, and 1,100 feet at base along the valley, and 3,000 feet long at top, and 600 feet at bottom across the valley. The bed of the river slopes at about 250 feet in the mile; and the depth of water in the newly-formed lake on the 13th and 14th December was 450 feet, the water then rising at the rate of 8 inches a day, though the flow of water in the mountain rivers was then at its slackest. Colonel Pulford writes as follows, on the probable future rise of water and the ultimate condition of the dam :—

"The present amount of water running into the lake is roughly about 260 cubic feet per second. During the winter rains there will be the addition due to a 12 inches fall over 84 square miles, which is the area drained by the river above the dam. The increase due to the snow-melting may be put at 2,120 cubic feet per second.

"Taking these several additional sources of supply into account, there seems every reason to suppose that the rise of water in the lake will be as follows :—

"Area of lake at present equals roughly 1 square mile—

"(*a*) Rainfall of 12 inches over 84 square miles $= 5,280^2 \times 1 \times 84$ cubic feet, which for one square mile of lake gives a rise of 84 feet.

"(*b*) In addition to rainfall there will be rise due to the present rate of inflow of, say, 8 inches per day up to date of snow beginning to melt, say, 1st April 1894. Up to that date, therefore, the rise in lake due to ordinary inflow will be 8 inches $\times$ 110 days $= 73$ feet. Up to 1st April 1894, therefore, the total rise will be 84 feet $+$ 73 feet $= 157$ feet, leaving a margin of $350 - 157 = 193$ feet from water-level to top of dam. Now the rate of rise due to snow-water influx will be eight times that due to the present ordinary flow of the river, since the floodmarks show that during snow-melting (as above stated) the river flow is 2,120 cubic feet per second, whilst present flow is 260 cubic feet per second. This, it is seen, gives a rise of 8 inches daily; and hence the rise to snow-melting may be put at 8 $\times$ 8 inches $= 64$ inches, or as the area of the lake will be increasing and slopes of hillside are about 35°, we may put this rise at 48 inches, or 4 feet per diem. Hence it will require $\frac{193}{4}$ days $= 48$ days after 1st April 1894 for the lake water to rise to the top of the dam. The date of this event may therefore be placed at about the middle of May 1894. As to what will take place when the water passes over the dam, it is difficult to speak with any approach to certainty. The first rush of water will necessarily be very severe, and I think that at least 250 feet or so of the dam at the top will gradually be carried away. After that it may possibly happen that the main portion of the dam will get thoroughly jammed and consolidated together so as to form a permanent lake with a natural outfall over the big rocks forming the dam."

Colonel Pulford also adds an account of a previous occurrence of the like kind :—

"A few years ago a very heavy flood was caused in the same river Birhi Ganga and Alaknunda by a heavy landslip falling into a lake which had been formed some 8 or 9 miles higher up the valley than the present slip. The lake was called Gudyar Tal, and had been in existence for many years; probably it had been formed originally by a similar slip to the one at Gohna. The result of the heavy slip falling into the lake was that the entire basin was filled up and the water forced over the dam which held it up down into the bed of the stream. This occurred in 1869 during the rains, and the results were very disastrous. A large number of pilgrims and others were drowned, and the lower part of Srinagar Bazar was washed away, and the lower end of Nand Pryag bridge was washed away. In addition the bridge at Chamoli, wnich is 12 miles below Gohna, was destroyed. Many of the bridges now up were not erected at the time of this heavy flood. They tell me that all trace of the former lake has been obliterated, and the channel is now very much like the other watercourses near it."

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894.

SUBSTANCE.	For whom.	Result.
One specimen of coke	H. MACLEOD, Bengal Coal Co., Ld., Calcutta.	Proximate analysis with calorific power and sulphur determination.
One specimen of quartz schist with iron pyrites.	F. T. VERNER	Assayed for gold.
One specimen of chlorite schist with copper pyrites.	KILBURN & Co., Calcutta.	Analysed for copper.
One specimen of quartz with iron pyrites.	H. C. MILLER, District Engineer, E. I. R., Howrah.	Assayed for gold.
One specimen of coal, from Japan.	H. MACLEOD, Bengal Coal Co., Ld., Calcutta.	Proximate analysis with calorific power.
One specimen of coal, from the Ramnagar quarry, Barakar.	MAHARANI HARA SUNDRI DAVI, Searsole, Rajbati.	Proximate analysis with calorific power.
One specimen of coarse river sand consisting chiefly of quartz, spinel, garnet, magnetic iron, bits of slate, and mica.	BALMER, LAWRIE & Co., Calcutta.	Assayed for gold.
One specimen of quartz, with iron pyrites, from the "Rees Reef," Pahardiah.	A. MERVYN-SMITH, Oriental Prospecting Syndicate, Ld., Calcutta.	Assayed for gold.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
A specimen from the bed of the Atrai River, Joyganj, Dinajpur District, supposed to be peat.	W. C. MACPHERSON, I.C.S., Officiating Director Department of Land Records and Agriculture, Bengal.	*Quantity received, 15lbs.* Moisture . . . 20·06 Volatile matter, exclusive of moisture . . 30·16 Fixed carbon . . 10·06 Ash . . . . 39·72 100·00 Does not cake. Ash, reddish brown.
One specimen of "Blanket sands," and one specimen of quartz with chlorite schist and iron pyrites, from Chota Nagpore.	A. MERVYN-SMITH, Oriental Prospecting Syndicate, Ld., Calcutta.	Assayed for gold.
One specimen of coal .	GILLANDERS, ARBUTHNOT, & Co., Calcutta.	Proximate analysis with calorific power and sulphur determination.
A specimen found in the Garhwal District, supposed to be molybdenite or sternbergite.	W. R. PARTRIDGE, I.C.S., Deputy Commissioner, Garhwal.	Carbonaceous shale (graphitic).
A specimen of limonite crystals from Chaibasa, supposed to be manganiferous.	A. W. WALKER, Chaibasa, Singbhum.	Tested for manganese.
A specimen "from an old pit (in the transitions) Nawanagari, Sihaol Tahsil, Rewah State, close to rich iron-ores" for indication of any other metal.	P. N. BOSE, Geological Survey of India.	Tested for gold—contains none.
Two specimens for examination.	S. B. BOSS, Geologist to the Nepal Government, Nepal.	= Iron pyrites, and artificial glass.
A packet of "stones found in an old ruby mine near Papun, Salween District, Tenasserim," for report.	HARRY L. TILLY, Secretary to the Financial Commissioner, Burma.	Small fragments of spinels and garnets of kinds often found associated with rubies, and as often not so found. In themselves they indicate nothing of value.
Specimens from the Karharbari coal-field, for examination.	W. SAISE, Manager, E. I. R. Co.'s. Collieries, Karharbari, Giridih.	*Karharbari Coal-field.* Fine-grained olivine dolerite, *Karharbari coal-field. Intrusive Lower Seam = Dyke No. 5 or Jogitand dyke of Hughes Memoirs. Geological Survey of India, Vol. VII, 239.* Biotite amphibole peridotite. *800 ft. above main seam.* Olivine dolerite. *Ranigang coal-field.* Calcareous and micaceous sandstone.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		Raneeganj Coal-field.
		Calcareous and micaceous sandstone.
		Raneeganj Coal-field.
		Quartz-schist with green muscovite and eyes of calcite.
		Rock from Bhal Hill.
		Consists of quartz and felspar crystals with small quantities of brown felsitic, or even glassy matrix with microlites like the matrix of a rhyolite. The quartz crystals show distinct signs of secondary enlargement, the older grains being full of bubbles and bands of inclusions. The rock appears to be a felspathic grit which has been partially fused.
		Raneeganj Coal-field, Raneeganj A. *series, Balrooi seam horizon.*
		Decomposed "mica-trap" probably originally mica-peridotite.
		B. *Intrusive in Karharbari Lower seam.*
		Decomposed "mica-trap."
		C. *Karharbari Coal-field.*
		Slightly micaceous sandstone with angular quartz-crystals and ferruginous cement.
		D. *Karharbari Coal-field, Lower seam.*
		Micaceous sandstone with angular quartz crystals.
		E. *Karharbari Coal-field.*
		Clay.
Specimens of rocks from Bellary.	R. BRUCE FOOTE, late Geological Survey of India.	*In the Pass south of Halakandi, Bellary.* $\frac{7}{886}$ *26-1-86. Slide 1195.*
		Epidiorite, approaching hornblende schist. Actinolitic hornblende, quartz-felspar, mosaic and magnetite. S. G. 2·97.
		Kudatami, Bellary. $\frac{7}{887}$ *1-2-86. Slide 1196.*
		Olivine-augite-enstatite-biotite-anorthite rock. The dusty magnetite present is a result of alteration principally of olivine-serpentine also in small quantities; otherwise the rock has a fresh appearance. Olivine in rounded grains is the oldest constituent; plagioclase-felspar (basic varieties) the youngest; the intermediate minerals are not so easily determined. Enstatite, slightly pleochroic. S. G. 3·14.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		West of Tekkalkota, Bellary Taluq. 8/788 *13-12-86. Slide 1197.*
		Grey rock approximating granite in composition, but quartz and felspar crystals have been smashed into a schistose mosaic with production of fine mylonitic structure. S. G. 2·68.
		From a "neck," Dewurruguddu Id. Falls of Kistna, Raichur Doab. 8/798 *21-2-88. Slide 1198.*
		Quartz and felspar in felsitic base, which has turned red by oxidation of the iron. S. G. 2·52.
		Black hill, West of Maski, Raichur Doab. 8/801 *13-2-88. Slide 1199.*
		Diorite with large porphyritic crystals of hornblende. Rock considerably altered with formation of epidote. S. G. 3·03.
		Inlier South of Manur, Bellary Taluq. 8/808 *15-3-88. Slide 1200.*
		Quartz-diorite. Quartz in part secondary, clear granules. Kaolinized felspars some at least plagioclase. Green hornblende and a green pleochroic mica, sphene in considerable quantity. Iron ores as magnetic granules. S. G. 2·81.
		Near Yemmigamer, Bellary Taluq. 8/810 *20 3-88. Slide 1201.*
		Quartz-diorite Felspars highly kaolinized. Epidote in small quantities. Green hornblende and a chloritic mineral; magnetite practically absent. S. G. 2·85.
		Hill, South of Kurnool District. 8/817 *30-11-88. Slide 1202.*
		Granulite with quartz, orthoclase, pleochroic mica, hornblende, sphene and plagioclase. Fine-grained granular, in places granitic in structure. S. G. 2·67.
		Tornagal Hill, Hospett Taluq, Bellary. 8/814 *6-4-88.*
		Hornblende granite with porphyritic crystals of orthoclase. S. G. 2·71.
		South of Nilgunda, Harapanahalli Taluq, Bellary. 8/813 *17-12-89.*
		Pyroxenite approaching eucrite. S. G. 3·22.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

No.	For whom.	Result.
		Yenkatampalli, 6 miles east of Uravakanda Guti Taluq, Anantapur. $\frac{9}{408}$ *29-1-85.*
		Fine-grained diorite approaching aphanite. S. G. 3·07.
		Mudkalpenta, South-East Valley, Sandur, Bellary. $\frac{9}{431}$, *20-3-86. Slide 1219.*
		Aphanite. S. G. 3·05.
		South-West of Uravakonda, Guti Taluq, Anantapur. $\frac{9}{108}$ *23-1-85. Slide 1214.*
		Large rounded crystals of orthoclase and plagioclase embedded in a microgranitic aggregate of quartz, felspar, hornblende and occasional sphenes. S. G. 2·69.
		Dyke East of Uparhally, Hospett Taluq, Bellary. $\frac{9}{427}$ *3-3-86. Slide 1218.*
		Augite-diorite, fine-grained. Identical with many of the dark-coloured dykes of Southern India. S. G. 3·03.
		Daroje, Hospett Taluq, Bellary. $\frac{9}{410}$ *23-4-85. Slide 1216.*
		Aphanite, with highly kaolinized, porphyritic crystals of felspar. S. G. 3·19.
		Devadura spur, Sandur Hills, Bellary. $\frac{9}{443}$ *25-3-86. Slide 1234.*
		Rock composed principally of quartz and felspar, some of the latter being plagioclastic. Micrographic intergrowths are common. Brown patches of iron oxide occurring in large quantities may be the remains of some original ferro-magnesian silicate; calcite has been formed in fairly large quantities. Isolated crystals of pyrites. S. G. 2·60.
		South of Hurina, Haddgalli, Bellary. $\frac{9}{480}$ *16-4-86. Slide 1205.*
		Micro-granulitic aggregate of quartz, felspar, hornblende, garnet, and possibly some other minerals. Banding displayed. Nature of original rock unknown. S. G. 2·94.
		Halakandi Pass, Bellary. $\frac{9}{481}$ *26-1-86. Slide 1206.*
		Augite-andesite-olivine-free basalt. Crystals of colourless augite and plagioclase set in a fine-grained matrix of magnetite, augite felspar, and possibly vitreous material. S. G. 3·03.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		West of Halakandi, Bellary. 9/467. *27-1-86. Slide 1207.* Hornblende schist.
		West by South of Yettan Budihal, Bellary. 9/187. *21-1-86. Slide 1208.* Epidiorite. Large crystals of green hornblende in microgranular matrix of quartz and felspar with granular sphene, (?) rutile magnetite and colourless (?) augite. S. G. 2·96.
		Karigutta Hill, East of Seringapatam Id., Mysore. 9/87. *15-2-87. Slide 1211.* Diorite-felsite: felsitic base with porphyritic crystals of plagioclase, hornblende (partially converted to epidote and chlorite), sphene and magnetite. S. G. 2·62.
		Ram Drug, Alur Taluk, Bellary. 9/488. *21-1-87. Slide 1212.* Hornblende-granitite with sphene and pleochroic mica. S. G. 2·66.
		Verupur Hill, Bellary Taluq, 9/78. *13-12-87. Slide 1213.* Augite-syenite. Augites green and slightly pleochroic with green hornblende. Considerable quantities of plagioclase amongst the smaller crystals, hence approaches a diorite. S. G. 2·81.
		Close to road between Permadavanhalli Bungalow and Joladarathi, Bellary Taluq. 9/75 and 9/45. *30-11-86. Slides 1210, 1221, 1222* "Blotchy diorite." Highly decomposed porphyritic diorite in which epidote, calcite, chlorite, kaolin and quartz have been formed as secondary minerals. S. G. of 9/75 = 3·02; S. G. of 9/45 = 2·79. Specific gravity necessarily variable in different specimens.
		Mudikalpenta, South-East Valley, Sandur, Bellary. 9/217. *20 3-86. Slide 1220.* Decomposed aphanite. S. G. 3·03.
		South of Nilgunda, Harapanahalli, Taluq Bellary. 9/818. *17-12-89. Slide 1233.* Pyroxenite, approaching eucrite.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
Rocks from the Khojak Range.	C. L. GRIESBACH, Geological Survey of India.	*A.—Main mass of Range north of the Gwajsha defile, South-East of Khwaja Amran.* Granitic in structure. S. G. 2·64. Composed of *orthoclase* much kaolinized and often in form of microcline. *Quartz* frequently intergrown with the orthoclase forming imperfect micro-graphic structure. *Plagioclase*-felspars, often zoned by successive growths of increasing acidity. *Biotite* in small crystals generally as nest-like aggregates. *Magnetite* generally with the biotite. *Sphene* very rare. Minerals given in order of approximate proportions. The rock may be named *Biotite-Granite* approaching granitite (= Granitite of Rosenbusch). *B.—Near boundary between A and "Trap-belt," Gwajsha defile, south-west of the Khwaja Amran.* Granitic or micro-granitic in structure, beautifully micro graphic in places. S. G. 2·68. The rock approaches A. in composition, but is slightly more basic and contains less potash-felspar. Biotite is present in larger quantities, but still in small bunches, and in the plagioclase crystals, granules of epidote have been developed in considerable quantity from the kaolinized felspar. Magnetite is also present and more rarely sphene. A rock with this mineral composition and structure might occur as a dyke-like extension from a main mass like A.—Granitite approaching quartz-diorite. *C.—Near South-West end of the ridge of A. Gwajsha defile, South-West of Khwaja Amran.* Granitic to micro-granitic in structure, and occasionally micro-graphic. S.G. 2·72. More basic than B. with more plentiful development of biotite and plagioclase. Apatite is present also in large numbers of minute acicular crystals. Granular magnetite and sphene more abundant. The quartz often in micro-graphic intergrowths with the felspar. Plagioclase almost invariably zoned, the cores of more basic material being generally kaolinized. Rock = Quartz-biotite diorite. *D.—From main mass of "Trap-belt" near C. Gwajsha defile.* Granitic in structure approaching granulitic. S. G. 2·89.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		Hornblende decidedly the most abundant constituent. Pleochroism, a=yellowish-green, b = grass green c=blue green. Plagioclase in zoned crystals is the next most abundant mineral. Biotite, quartz, magnetite and sphene in smaller quantities. Epidote and calcite occur as the result of secondary alteration.=Diorite.
		NOTE.—The biotite in all four of the above rocks shows the same kind of greenish pleochroism. The differences in mineral composition might easily be obtained in rocks derived from the same magma at different periods of consolidation.
		E.—From outer margin of the "Trap-belt," Gwajsha defile.
		The main mass of the rock resembles an epidiorite or a rock formed as the result of decomposition and slight crushing of D. The plagioclase-felspar crystals are highly kaolinized, but still show their lamellar twinning. The hornblende and biotite have contributed to the formation of chlorite, but fragments of the original minerals still preserve their optical characters sufficiently for recognition. But there are streaks and patches of brown material with small granular augites and magnetites in a fine-grained groundmass like that of a basaltic andesite, and the patches being very ill defined they suggest partial re-fusion of the rock in some manner not explainable from the hand specimen alone. Veins of calcite and granular quartz have been produced *since* the above changes took place in the rock.
		F.—From the outer margin of the "Trap-band," Gwajsha defile.
		Development of pistacite (epidote) in a rock similar to D. or E. Calcite and granular quartz have developed also as the result of secondary action with the epidote. Acicular actinolite, magnetite, etc., occur as relics of the original rock. S. G. 3·16.
		G.—From margin of "Trap-belt," Gwajsha defile.
		Highly crushed aggregate of quartz, felspar and biotite with small quantities of magnetite. Some of the felspar is orthoclastic and the rock might very well be simply a crushed form of a type either identical with or closely related to A.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894—contd.

SUBSTANCE.	For whom.	Result.
		II.—From the margin of the "Trap-belt," Gwajsha defile.
		A brecciated and crushed micrograsitic rock approaching A in composition but very much more finely grained. Ferruginous material cementing the fragments. Cracks produced *since* brecciation and cementation have been in-filled with calcite.
		I.—From margin of "Trap-belt," Gwajsha defile. Diorite containing patches of fine-grained rock like those in E. Epidote occurs in small quantity. The rock seems identical with E, and it must have been in this rock that the epidote of F was produced.
		L.—Margin of "Trap-belt" and Gwajsha pass. Granular aggregate of plagioclase, (?) orthoclase, quartz, magnetite and a decomposed ferro-magnesian silicate, probably biotite. Origin of rock doubtful, probably igneous.
		K.—From margin of "Trap-belt," Gwajsha defile.
		Finely laminated and decomposed rock, possibly orginally similar to L.
		M.—From margin of "Trap-belt," Gwajsha defile.
		Foliated variety of D, E, or I. Now in the form of a hornblende-schist.
		N.—From grit-beds North-East margin to the Khwaja Amran mass of igneous rocks.
	*	A composite grit in which the grains are cemented and available crevices in-filled with calcite. Grains imperfectly rounded; many of them seem, however, to have been attacked by the infiltrated carbonate of lime, or to have been deformed by pressure. The minerals and rocks are of comparatively low specific gravity—averaging about 2·65; and isolated fragments of heavy minerals are absent. Quartz fragments with bands of inclusions like those of plutonic rocks are common and might of course have been derived from any granite or quartz bearing crystalline rock. Fragments of plagioclase, orthoclase, felspar occur as isolated grains; but most of the felspar occur as constituents of rock fragments. Flakes of biotite are mostly changed in part to chlorite.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November and December 1893 and January 1894 - contd

SUBSTANCE.	For whom.	Result.
		Of the rock fragments there are fairly fresh specimens of a rhyolite with bipyramidal and corroded quartz crystals, a considerable amount of plagioclase amongst the felspathic constituents, and colourless and coloured mica in a felsitic or vitreous matrix showing distinct flow-structures and imperfect spherulitic and axiolitic aggregations of microlites. A rock of this type might very well be a volcanic representative of the granitite A. There are also fragments of andesites, bits of diorites with similar developments of epidote, rare pieces of granophyre (micrographic intergrowths of quartz and felspar); but nothing distinctly basic in character; in fact the grit seems composed of fragments of the rocks A to M, together with pieces of volcanic origin, possibly representative of that series.
		O.—From the volcanic grit-beds North-East of the Khwaja Amran mass.
		The fragments are sub-angular to rounded as in the former case; but although calcite is again present in infilling cracks, the cementing material is much more ferruginous in character and some of the granules appear to be ferruginous clay with cracks infilled with calcite like minute septarian nodules. Whilst granules of quartz are present in this grit it is by no means so plentiful as in the case of N, and the rock granules are moreover almost wholly of the dioritic series with considerable display of epidote. The average specific gravity of the fragments is 2·71, and thus as might be expected heavier than those of N. Some of these are distinctly foliated.
		P.—From the shaley portion of the grit-beds North-East portion of the Khwaja Amran mass.
		Compact mass of calcareous clay with minute quartz grains.
		Q.—Nummulitic limestone close to the base of "Kojak" shales, near Spintisha.
		(Not further examined).
		X.—From the "trappoid" beds in the Chehiltan range, West of Quetta.
		Small fragments of quartz, quartzite, and intermediate igneous rocks (diorites and andesites); limestone and mica-plates are cemented with argillaceous material. Cracks are filled with calcite which has infiltrated into all available crevices.

Notifications by the Government of India during the months of November and December 1893 and January 1894, published in the "Gazette of India," *Part II.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	Remarks.
Revenue and Agricultural Department.	No. $\frac{2837}{220}$, dated 24th November 1893.	W. B. D. Edwards, Assistant Superintendent, Geological Survey.	Furlough on Medical Certificate.	4th November 1893.	...	...

Annual increments to graded officers sanctioned by the Government of India during November and December 1893 and January 1894.

Name of Officer.	From	To	With effect from	No. and date of sanction.	Remarks.
Dr. F. Noetling, Palæontologist, Geological Survey.	700	750	1st October 1893.	Revenue and Agricultural Department No. $\frac{2770}{213}$, dated 8th November 1893.	
C. S. Middlemiss, Deputy Superintendent, Geological Survey.	660	700	1st November 1893.	Revenue and Agricultural Department No. $\frac{2830}{217}$, dated 22nd November 1893.	

Notifications by the Government of India during the months of November and December 1893 and January 1894, published in the "Gazette of India," *Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.*

Department.	No. of order and date.	Name of Officer.	From	To	Nature of appointment, etc.	With effect from	Remarks.
Revenue and Agricultural Department.	No. $\frac{114}{35}$, dated 12th January 1894.	Dr. H. Warth.	Officiating Superintendent, Government Central Museum, Madras.	Deputy Superintendent, Geological Survey.	Substantive, permanent.	4th December 1893.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. HUGHES	On furlough.	
C. L. GRIESBACH	Loralai	Loralai.
R. D. OLDHAM	On furlough.	
P. N. BOSE	Rewa	Rewa.
T. H. D. LATOUCHE	Sukkur	Sukkur.
C. S. MIDDLEMISS	Jalarpet	Jalarpet.
W. B. D. EDWARDS	On furlough.	
P. N. DATTA	Bhandara	Bhandara.
F. H. SMITH	Harnai	Harnai.
F. NOETLING	Calcutta	Calcutta.
HIRA LAL	Calcutta	Calcutta.
KISHEN SINGH	Babar Kach	Babar Kach.

DONATIONS TO THE MUSEUM.

FROM 1ST NOVEMBER 1893 TO 31ST JANUARY 1894.

A small specimen of quartz, from the Elephant Rocks, Shevaroy Hills, Salem District, Madras.

PRESENTED BY THE DISTRICT FOREST OFFICER, SALEM.

A block of steatite, from the Marble Rocks, Jubbulpore; and another from Kanheri Village, Bhandara District, Central Provinces.

PRESENTED BY THE OFFICIATING REPORTER, ECONOMIC PRODUCTS TO THE GOVERNMENT OF INDIA.

Hercynite, in small fragments, from Chinnamalai, Erode Taluk, Coimbatore District.

PRESENTED BY H. WARTH, OFFICIATING SUPERINTENDENT, GOVERNMENT CENTRAL MUSEUM, MADRAS.

A cut specimen of fine-grained sandy shale, and two of fine-grained sandstones, from Indrajurba, near the Damuda River, Hazaribagh District.

PRESENTED BY N. BELLETTY.

Two large pieces of Columbite; a large block showing junction of very coarse mica granite with mica schist; and decomposed iron ore, from the Dattoo Mines, Pannanore Hill, Nawadih, East Indian Railway.

PRESENTED BY H. H. FRENCH.

A specimen of quartz, with iron pyrites and gold, from the "Rees Reef," Pahardiah, Chota Nagpore.

PRESENTED BY T. F. VERNER.

Large specimens of Pumice, from Cardamum Island, Laccadives.

PRESENTED BY SURGEON-CAPTAIN A. W. ALCOCK, M.B.

ADDITIONS TO THE LIBRARY.

FROM 1ST OCTOBER TO 31ST DECEMBER 1893.

Titles of Books. *Donors.*

AGUILERA, *Jose G.*, and ORDONEZ, *Ezequiel.*—Datos para la Geologia de Mexico. 8° Pam. Tacubaya, 1893. THE AUTHORS.

BLACKENHORN, *Dr. Max.*—Beiträge zur Geologie Syriens die Entwickelung des Kreidesystems in Mittel-und Nord-Syrien. 4° Cassel, 1890.

BOYD, *R. N.*—Coal Pits and Pitmen. 8° London, 1892.

BRONN'S Klassen und Ordnungen des Thier-Reichs. Band III, lief. 3-6 and Supplement lief. 1; Band VI, Abth. IV, lief. 46-49, and Abth. V, lief. 40-41. 8° Leipzig, 1893.

CASARIEGO, *D. Enrique Abella Y.*—Descripcion Fisica, Geologica y minera en Bosquejo de la Isla de Panay. 8° Manila, 1890. THE AUTHOR.

COOKE, *Josiah P.*—Elements of Chemical Physics. 8° London, 1886.

COTTEAU, PERON and GAUTHIER.—Echinides Fossiles de L'Algerie. Fasc. 6-9 4° Paris, 1880-1883.

DALL, *William Healey.*—Republication of Conrad's Fossils of the Medial Tertiary of the United States. 8° Philadelphia, 1893.

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DANA, *J. D.*—The System of Mineralogy. 6th Edition. 8° London, 1892.

DAUBREE, *A.*—Application de la Méthode experimentale au Role Possible des Gaz Souterrains dans L' Histoire des Montagnes Volcaniques. 8° Pam. Paris, 1892.

ETHERIDGE, *Robt.*—Fossils of the British Islands. Vol. I. Palæozoic. 4° Oxford, 1888.

GARDNER, *J. S.*—Iron work from the earliest times to the end of the Mediæval period. 8° London, 1893.

GEIKIE, *James.*—Fragments of Earth Lore. 8° Edinburgh, 1893.

GEIKIE, *Sir Archibald.*—Text Book of Geology. 3rd Edition. 8° London, 1893.

HOERNES, *Dr. Rudolf.*—Erdbebenkunde. 8° Leipzig, 1893.

KAYSER, *Dr. Emanuel.*—Lehrbuch der Geologie. Part 2. 8° Stuttgart, 1893.

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LUNGE, *George.*—A Theoretical and Practical Treatise on the Manufacture of Sulphuric Acid and Alkali, with the Collateral Branches. Vols. I-III. 8° London, 1891.

MARTIN, *K.*—Bericht uber Eine Reise Nach Niederländisch West-Indien und Darauf Gegründete Studien. Vols. I & II. 8° Leiden, 1887-1888.

" Niederlœndische und Nordwestdeutsche Sedimentœrgeschiebe Ihre Uebereinstimmung Gemeins-chaftliche Herkunft und Petrefacten. 8° Leiden, 1878.

MILNE, *John.*—Earthquakes and other Earth Movements. 3rd Edition. 8° London, 1893.

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MUSHKETOFF, *W.*—A Geological and Orographical description of Turkestan. 8° St. Petersburg, 1886.

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PHILIPPSON, *Dr. A.*—Der Peloponnes. Abth. I & II. 8° Berlin, 1891-1892.

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ROMANOFSKY.—Notes on the Geology of Turkestan. Vols. II & III. 4° St. Petersburg, 1884 & 1890.

SAWYER, *A. R*—Miscellaneous Accidents in Mines. 8° London, 1889.

SCOTT, *Alexander.*—An Introduction to Chemical Theory. 8° London, 1886.

THORPE, *T. E.*—A Dictionary of Applied Chemistry. Vol. III. 8° London, 1893.

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American Geologist. Vol. XI, Nos 4-6, and XII, Nos. 1-2. 8° Minneapolis, 1893.

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American Naturalist. Vol. XXVII, Nos. 320-322. 8° Philadelphia, 1893.

Annalen der Physik und Chemie, Neue Folge, Band L, heft. 2-3. 8° Leipzig, 1893.

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Annales de Géologie et de Paléontologie. 4° Palerme, 1893.

Annals and Magazine of Natural History. Vol XII, Nos. 70-72. 8° London, 1893.

Athenæum Nos 3438-3450. 4° London, 1893.

Beiblätter zu den Annalen der Physik und Chemie. Band XVII, Nos. 8-10. 8° Leipzig. 1893.

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The Indian Engineer, Vol. XVII, No. 337 to XVIII, No. 350. 4° Calcutta, 1893. J. MACINTYRE.

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BENGAL.—Report on the Agriculture of the District of Cuttack. Flsc. Calcutta, 1893. BENGAL GOVERNMENT.

BOMBAY.—Brief Sketch of the Meteorology of the Bombay Presidency for 1892-93. Flsc. Bombay, 1893. METEOROLOGICAL REPORTER TO BOMBAY GOVERNMENT.

„ Selections from the Records of the Bombay Government. New Series, Nos. 271-272. Flsc. Bombay, 1893. BOMBAY GOVERNMENT.

INDIA.—Census of India, 1891. Report on the Census of Coorg, and Vols. XIII—XV containing Report on the Census of Madras, with Tables. Flsc. Calcutta, 1893. REVENUE AND AGRICULTURAL DEPARTMENT.

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GOVERNMENT OF INDIA.

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G. I. C. P. O.—o. 31 D. G. Survey.—12-3-94.—

ERRATA.

RECORDS, VOL. XXVII, PART 3.

The Giridih (Karharbari) Coal-field

Page	87,	line 1,	from top,	for *Plates* read *Maps*.
,,	87	,, 1	,,	and for *III* read *I*.
,,	87	,, 13	,,	for *section* read *section on EF*.
,,	87	,, 19	,,	for *Plan* read *Map*.
,,	87	,, 23	,,	for *inclines* read *incline*.
,,	87	,, 38	,,	for *VII* read *VI*.
,,	88	,, 7,	from bottom,	for *100* read *200*
,,	89	,, 10,	from top,	omit *three*.
,,	89	,, 16,	from bottom,	parenthesis to be placed after *numerously* and omitted after *Seam*.
,,	91	,, 6,	from top,	for *Dikes* read *Dykes*.
,,	94	,, 13,	from top,	for *are* read *is*.
,,	95	,, 13,	from top,	for *rubbed* read *robbed*.
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,,	95	,, 26	,,	for *square* read *shot*.
,,	97	,, 9,	from bottom,	for *8* read *3*.
,,	97	,, 6	,,	for *VII* read *VIII*.
,,	99	,, 13	,,	for *women*), *Santas* read *women and Santals*).

Plate VII,	for figure	*1*	read	*6*.
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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1894. [November.

Note on the Geology of Wuntho *in* Upper Burma, *by* FRITZ NOETLING, PH.D., F. G. S., *Palæontologist*, *Geological Survey of India*, *with a map*.

Geographical features.—The area described in the following pages comprises part of the Wuntho sub-division of the Katha district in Upper Burma. It extends, roughly speaking, between Htygaing on the Irrawaddi, and the Mu valley; in its eastern part only low hills rise from the surrounding plains, but in its western part the large massive of the Maingthong hills form a tract of approximately 75 miles in length.

The Maingthong hills, which I partly examined begin near Lat. 23° 45′ and Long. 90° 20′ near the junction of the Daungyu Choung with the Mu river. From this point the hills extend in a nearly northerly direction, the tract widening out gradually till it reaches its greatest breadth of 30 to 35 miles near Lat. 24° 5′.

It may be said to be limited by the broad valleys of the Mu and its tributary the Nam-Maw in the west, but its eastern boundary is less sharply defined. In the southern part the broad Wuntho valley forms the boundary, but further towards north the low hills to east come quite close up to the central massive forming for some distance a low watershed between the Meza and Mu river. North of these low hills the eastern boundary is again well defined being formed by the broad valley of the Meza river.

The highest point in this hilly tract is Maingthong hill (5,510 feet), the south-western spurs of which have been geologically examined.

The Toung-thon-lon (5,565 feet) at Lat. 24° 56′ and Long. 95° 52′ may possibly form the northern continuation of the Maingthong tract, but it was not visited.

Geological features.—I can only give a rough outline of the geological features of this area, owing to the almost unsurmountable difficulties, which the dense, nearly impenetrable jungle places in to the way of geological researches. Here and there a rock protrudes from under the thick vegetable mould which everywhere covers the ground. But nothing can be seen of the dip and strike of the strata. The trained eye, however, learns very soon to judge from the difference of the surface soil, whether a change in the nature of the underlying rocks has taken place. For instance, it is always easy to distinguish whether there are tertiary strata or diorite *in situ* below the surface soil, but the exact boundary lines must be guessed at. Even the valleys afford little opportunities for the geologist, owing to the impenetrable jungle.

As far as I could ascertain only eruptive rocks take part in the Maingthon hill tract whilst the surrounding low hills to the east, sormation of the the eruptive mass consist of miocene beds, both of the lower or h and west of the upper or Irrawaddi group. Older formations occur only close to Chindwin and river, where the low ridge which runs almost due north, near Htygain the Irrawaddi by mica schists, with an easterly dip; some traces of metamorphized c is formed limestone may be seen on the eastern side of the ridge which forms the rboniferous between the Meza and Mu river, the crest of which is formed by an extensive bed serpentine dyke.

A.—ERUPTIVE ROCKS.

1. *Quartz Diorite.*—The rock which is chiefly developed in the Maingthong hill tract is a crystalline rock which from its outward appearance must be placed between granitites and quartz diorites.

So far as it is known the quartz diorite occupies chiefly the central part of the tract; it is well seen on the road from Wuntho to Pinlebu, between the villages of Myelin and Hethat, that this is so may be seen on the footpath which leads from Wuntho to Myelin, but the locality where I found it best developed is the Tayaw-choung, a feeder of the Yu river; here enormous masses may be seen in rounded forms covering the slopes.

There is sufficient reason to believe that the quartz diorite is not only developed in the shape of a central mass, but that numerous dykes radiate from the centre, which show a considerable difference from the central mass; such a vein may be seen in the Nam-Maw ravine east of Mawteik where it undoubtedly penetrates the black rock (aphanite). Occasionally veins of white quartz may be seen in the diorite, but so far as I know they are not metalliferous.

2. In close connection with the diorite occurs a hard black rock which is developed either in homogenous masses or is well stratified. This mode of occurrence may be seen in the Nam-Maw ravine, east of Mawteik; after having passed Mawteik where a truly intrusive rock of the trap type can be seen, an exceedingly hard dark rock forms the bed of the river; for about half an hour this rock may be traced without any apparent change being noticed, excepting occasional fissures; then the rock disappears beneath the jungle, and when it crops out again, it is apparently of the same type, but now well stratified. The strike is 45° N.E.-S.W. and the dip 45° W. It is crossed by a system of jointing, running 340° N. N.-W.-S. S. E. and dipping 62° E.

Mr. Holland describes this rock as follows:—A compact bluish-green rock breaking with a semi-conchoidal fracture, studded with minute grains of magnetite pyrites and pyrrhotite, the last-named minerals occurring also in irregular patches. Specific gravity 2·86. Under the microscope the rock presents the characters of a volcanic agglomerate rather than an ordinary lava or a dyke rock. Fragments of plagioclase felspars, hornblende and augite in all stages of decomposition are mixed with opaque grains of magnetite and pyrites in a microlithic groundmass. It contains a trace of gold but not enough for estimation.

Mr. Holland further remarks that only the occurrence in the field can decide exactly the origin of the rock, but from the microscope alone it seems to be a consolidated volcanic ash.

Mr. Holland's supposition is perfectly correct; when I first discovered this rock it struck me at once as not being of truly sedimentary origin, although being perfectly stratified. In fact the bedding goes so far that the grains and patches of magnetite pyrites run parallel to it. My first idea was that this must be a consolidated volcanic ash, very probably deposited in water. At all events under this circumstance the hard bluish rock mentioned above is also a cemented and hardened volcanic ash on the top of the stratified beds.

This hardened volcanic ash may be seen all along the outskirts of the Maingthong hill tract forming particularly the surrounding region; I first noticed it near Padeingon, about 15 miles in a straight line north of Wuntho, and from there I traced it all along the lower hills which form the outskirts *viâ* Pinlon, Kyaungon, as far as Wuntho; on the road from Wuntho to Pinlebu between the 7th and 8th mile where there are extensive old gold-diggings, this hardened volcanic ash shows, according to Mr. Holland, exactly the same composition as that from Mawteik which is not less than 28 miles in a straight line distant from that place. Here the simultaneous occurrence of the stratified and the non-stratified beds can also be seen, and the first are apparently the lower; a sample of the non-stratified rock exhibits the following characters:—A coarser grained rock than that from Mawteik, presenting the characters of a compact and altered agglomerate. There is a considerable development of epidote at the expense of the decomposing felspathic material which is in large quantities. Fragments of amygdaloidal andesite are occasionally found included and undergoing the general decomposition. Specific gravity 2·884. I need hardly add that it also contains numerous specks of magnetite pyrites.

To me it seems most probable that the diorite and the volcanic ash are in generic connection, although this has not been actually proved yet; the probably sub-marine diorite eruptions were accompanied by large showers of ash which form now these pseudo-sedimentary rocks. Undoubtedly, subsequent eruptions produced dykes, which intruded into the surrounding ash masses and these dykes chiefly attract our attention. They were of two types—one, closely allied in composition to the diorite; the second, chiefly consisting of felspathic quartz which contains a more or less considerable quantity of auriferous pyrites.

(*a*) *Pyritic veins* (*auriferous.*)

The known pyritic veins are only found on the eastern side of the Maingthong hill tract, but I have not the slightest doubt, that subsequently they will be found at other places within the ash-girdle. Beginning from the north the following localities are known where these veins occur:—

1. Gwegyi.
2. Toungni near Padeingon.
3. Chouk-paza-doung, close to Padeingon.
4. Theindoo-choung, near Pinlon.
5. Mayutha.

All these places are quite close to each other, the distance from Mayutha to Gwegyi being not more than 12 miles in a bee-line. So far as it has been observed the veins do not run in any particular direction, but I may be wrong here. Anyhow the small holes in which the veins were exposed, did not permit a definite opinion; only when their extent is known, can this question be decided. The

veins naturally vary in thickness, as well as in the quantity of pyritic ore which they contain. The thickest vein which I have seen is that of Toungni; the ore contained a comparatively small quantity of pyrites; on assay it yielded 4 dwt. 15 grs. of gold to the ton. The ore from Chouk-paza-doung which occurs in a vein of about 9 to 12 inches in thickness is much richer in pyrites, but it yielded only 1 dwt. 7 grs. of gold.

At Pinlon, of which Mayutha is probably only the continuation, the vein is about 4 inches in thickness, but consists nearly throughout of pyrites. On assay it yielded only a trace of gold, although there is seemingly a connection between the quantity of pyrites and gold contained in the ore; that is to say, the richer in pyrites the poorer in gold, this supposition requires however a great deal more confirmation before it can be accepted.

However it is not only the quartz veins to which the occurrence of auriferous pyrites is limited, much more frequently it is largely dispersed in small crystals through the ash; in fact we may say the occurrence in veins is only a concentrated form of the occurrence of the auriferous pyrites in the ash. Pinlon offers a good example of this; as above mentioned, there is a comparatively thin vein of pyrites traversing the volcanic ash, which itself shows not race of pyrites, at a distance of about 200 yards from the above place the ash, however, shows numerous small pyritic crystals and old diggings prove that the natives have been working here for gold. Typical localities of the second mode of occurrence of the pyrites are—

1. Gotama hill near Wepone, north of Wuntho.
2. Kyoukpyu, between the VII and VIII mile on the road from Wuntho to Pinlebu.
3. Nam-Maw east of Mawtcik, Pinlebu Sub-division.

Besides the above there are undoubtedly numerous other places; for instance the frequent occurrence of crystals of pyrites in the streams near Gyodoung (north of Wuntho) prove that it must be found west of that place.

(*b*) *Galeniferous veins* (*argentiferous*).

Besides the pyritic ore there occurs on the western side of the Maingthon hill tract a galeniferous vein of Cerussite under very similar circumstances. The first locality where I found it is called Kaydwin (Kay-lead, dwin-mine) situated in the ravine of the Nam-Maw, east of Mawteik and still further to the east from the place where the pyritic ash had been observed. As far as I was able to ascertain without making extensive diggings it is a vein of, as Mr. Holland describes it, an igneous rock of the aphanite group being composed principally of lath-shaped plagioclase felspars, hornblende, and relics of augites with considerable quantities of granular magnetite. The whole rock has been considerably decomposed; epidote has formed and veins of other products of decomposition occur. The strike of the vein is apparently N. N. E.-S. S. W.; but owing to the unfavourable position of the outcrop this could not be ascertained. The thickness varies, but in the average it is not less than 4 feet. The cracks of this vein are filled with veins of Cerussite, which forms thin layers encrusting the rock. According to Mr. Holland it yielded 69·1 per cent. of lead and 33 oz. 16. dwt. 4 grs. of silver to the ton of lead.

Following up the direction of the strike in a south-westerly direction at a distance of about six miles in a straight line, another locality called Mawkwin

exists where the natives have been digging for lead. The mode of occurrence being the same, it is undoubtedly that this place represents the southern continuation of the Kaydwin outcrop.

(*c*) *Salt springs.*

Another most remarkable occurrence within the area of the volcanic ash on the western side of Mainthong hill tract, is that of salt springs.

They are usually found in the bed of the streams where the brine oozes out from the rock. Such places are :—

Kyatngat in the Nammaw ravine.	
Kaydwin ,, ,, ,,	
Taungmaw ,, ,, ,,	
Natdaw ,, ,, ,,	
Mangyi ,, ,, ,,	
Mawkwin in the Tayaw ravine.	
Senan ,, ,, ,,	
Sagyin	
Magyibin	
Kya-wut-maw	
Sinsamaw	Nam of stream unknown, but close to the above.
Zibinmaw	
Nayaungbinmaw	

If the situation of these salt springs is fixed on the map it seems that they occur along a line which runs about north-north-west and that they are chiefly found at such places where the erosion of the streams has cut across it. It is therefore highly probable that these salt springs follow a line of fault, which seems in the main to run parallel to the Cerussite vein.

B.—THE YOUNGER FORMATIONS.

Maingthon hill tract is surrounded on all sides by tertiary strata, which in no way differ from those observed elsewhere in Burma. Yellowish soft sandstones and brown clays form the upper beds, and blue clays with ferruginous concretions, and grey sandstones, are predominant in the lower part. The tertiary strata come up quite close to Maingthon hill tract; in fact, they form part of it, and on its western side they compose the lowest spurs. Whether there is a line of disturbance between the tertiaries and the eruptive centre is difficult to say.

On the western side the older tertiaries or Chindwin group may be traced for a long distance; these beds are of small thickness comparatively, and form a narrow band which skirts the central massiv; it is followed by the upper tertiaries, the Irrawaddi sandstone, which is easily recognizable by its characterstic escarpments, facing east; there is no doubt that the Irrawaddi sandstone extends to the west as far as the Chindwin.

The general dip of the tertiaries is towards west.

On the eastern side the Chindwin sandstone has not been observed yet, but there is every reason to believe that it may yet be found. General dip towards east.

The way in which the tertiaries follow the contours of the central massiv convinces me that they were not only deposited along it, but that they once covered it entirely. The older eruptive massiv was only laid bare by the same action which

resulted in the folding of the tertiaries. Once laid open to denudation the softer tertiary strata were of course washed away easier than the hard diorite. As a result of this denudation the central diorite massiv protrudes in the form of a high, hilly tract from the surrounding low-lands of tertiary age. On the eastern side there are numerous outcrops of coal seams, which, beginning north, run as follows :—

1. Choukpyachoung between Mansigale and Pinmu.

The coal is exposed in the bed of a small stream; it forms two seams separated by a clayey parting; the following is the section in descending order :—

7 Clay.
6 Shaly coal, 18 inches.
5 Brown soft clay, 12 inches.
4 Shaly coal, 10 inches.
3 Good hard coal, 3 inches.
2 Shaly coal, 3 inches.
1 Clay of unknown thickness.

The coal, except the thin layer of 4 inch, is of very inferior quality, brittle, and very shaly; in fact, it can hardly be considered as more than a bituminous shale.

2. Tabawda-Choung a feeder of the Tayaw-Choung, about three miles south-west of Mansigale.

The coal seam crops out in a narrow, nearly inacessible ravine; the seam dips west at an angle of about 10°. The following is the section in descending order :—

9 Clay.
8 Shaly coal, 14 inches.
7 Brown bituminous clay, 12 inches.
6 Shaly coal, 7 inches.
5 Good coal, 6 inches.
4 Shaly coal, 1 inch.
3 Good coal, 6 inches.
2 Shaly coal, ½ inch.
1 Bluish clay of unknown thickness.

The coal is of good quality, but not of sufficient thickness to pay working.

3. Milaunggon, east of Pinlebu.

Here an outcrop of coaly shale, apparently in disturbed position, may be observed; it is absolutely of no commercial value.

4. Subokom, about the 34th mile from Wuntho.

The outcrop is found in the bed of a very narrow ravine, unfortunately much covered by jungle; unless exposed by trenches, not much can be said about this out-crop; but judging from the others, it is not very probable that it will prove of particular value. The seam dips west at an angle of apparently 10°. The following is the analysis of a sample of this coal :—

Moisture	7·68
Volatile matter	34·42
Fixed carbon	53·58
Ash	4·32

According to this analysis, the coal should form a very good fuel provided it exists in sufficient quantity.

5. Moungaw Stream, near Yuyinbyet village, south of Pinlebu.

Two outcrops can be seen here: the lower one is a seam of shaly, brittle coal of about two feet thickness imbedded in clay, the second shows a seam of 4 to 5 feet good coal covered by about 8 inch of shaly coal; the out-crop was unfortunately partly covered with water, which prevented further examination. Dip about 10° towards west. The following is the analysis of a sample of this coal:—

Moisture	6·60
Volatile matter	34·24
Fixed carbon	52·22
Ash	7·04

The coal is so exactly similar in composition to that from Subokom, that, considering the position of the two localities, it is highly probable that both belong to one and the same seam, of which the Moungaw out-crop is the southern continuation.

6. Wetabin-Choung, about 1 mile west of Engwe village on the Yu river.

I discovered only a seam of shaly coal here which closely resembled that of Milaunggon. However, another seam must be *in situ* in the same stream, which is hidden under the detritus, for fragments of good hard coal have been washed out and prove its existence higher up. According to the analysis it contained—

Moisture	8·28
Volatile matter	36·14
Fixed carbon	48·58
Ash	7·00

It is therefore in no way inferior to the coal of the above named two places.

C.—ECONOMIC VALUE OF THE MINERALS IN THE MAINGTHONG HILL TRACT.

1.—GENERAL CONDITIONS.

Before going into the details of the value of the minerals mentioned in Section B., it will be useful to discuss such questions first, which would apply generally to all mining operations in Wuntho, namely, accessibility, labour, water and fuel-supply.

As regards accessibility, there can be no doubt that the opening of the railway line to Wuntho has greatly facilitated mining enterprise in those parts of Burma. Without the railway, mining in such a country would be out of the question altogether; the forty odd miles from Htygaing, the nearest river station, to Wuntho, across a country which is a swamp for the greater part of the year, would never permit any mining enterprise. But even supposing the necessary tool and plant having safely arrived by rail at Wuntho, there still remains a good distance to be covered by carts. The pyrites mines are more favourably situated, the railway line running nearly parallel to the eastern spurs of the Maingthong hill tract; but there are still, in the most favourable case of Theindoo-choung and Mayutha at least 10 to 12 miles of very difficult country to be traversed by road; in the case of the other mines, the distance is greater still. It may be said, however, that, although the cost of transport is great, it would not be prohibitive in the case of the pyritic veins.

As regards the coal-mines, the nearest outcrop is 32 miles over a much broken country, from the railway station, a distance which in itself would render it an

unprofitable undertaking to work these mines, considering the favourable position of the Kabwet colliery, which is open to communication either by river or rail. The lead-mines are still more unfavourably situated, there is a cart road from Pinlebu to Wuntho (at present, however, only practicable during the dry season); but beyond Pinlebu, communication is rather difficult; the total distance from the railway station to the Kaydwin being not less than 68 miles over very broken country, which in my opinion will enhance the cost of transport so much as to make it a most unprofitable concern even if the ore contained 33 ounces of silver to the ton.

With regard to labour, it may at once be said, that to rely on local supply would wreck any mining enterprise from the very beginning. Probably one or the other local coolie, attracted perhaps by high wages, will for some time work in a mine, but it is more than doubtful whether they would take up the work in any number, and, what is the most important point, would persevere in it. The population consists chiefly, if not entirely, of agriculturists, who are not likely to give up their comparatively easy work, which affords them a sufficient if not ample livelihood, with plenty of spare time. If they could be induced to take up working in a mine, they would most probably only do so during the off season, and return to the cultivation of their fields when their presence is required. Labour must therefore be imported at undoubtedly considerable expense, if ever mining operations were started in those parts of Burma. Finally, another point must not be overlooked; Wuntho, in fact the whole of the Maingthong hill tract, is an excessively unhealthy and feverish country, as I have experienced myself. The death-rate amongst the coolies would be sure to rise to such a point that exorbitant wages would have to be paid to the labourers to induce them to stay on. The sanitary conditions would undoubtedly improve immediately the jungles were being cleared and the coolies fairly housed, but at the beginning the death-rate would certainly be a high one. There is plenty of water all the year round, an important matter, if it were to come to the setting up of stamping batteries, and there would be no lack of fuel, at any rate within the first twenty-five years, the country being thickly stocked with wood.

To sum up, accessibility in all cases, except the coal and lead mines, fairly good. Water and fuel plentiful; local supply of labour next to none.

2.—Value of the minerals.

Having dealt with the general conditions, on which mining enterprise in Wuntho will depend, it remains to discuss the value of the different minerals which are likely to be exploited. These are—

1. Auriferous pyrites.
2. Argentiferous Cerussite.
3. Coal.
4. Salt.

1. *Auriferous Pyrites.*—It must be understood that all the gold found in the Maingthong hill tract has been derived from the decomposition of iron pyrites, whether gold be found in specks, in the surface soil, or in small grains inclosed in the quartz. The sooner it is understood that the gold found in the quartz is not primary, but a residue of a chemical process, *i. e.*, the decomposition of the

iron-pyrites, the more will the difficulties be realized which will have to be encountered when exploiting these auriferous ores. I do not doubt that at the outcrop of the pyrites-veins metallic gold has been found, although I did not find it myself; the Choukpaza lode for instance shows unmistakeable signs that its outcrop had been worked by some body and for some purpose, and if the natives state that this purpose was the extraction of gold this statement is probably correct. I have also no doubt that the same may be the case with other localities, for instance, Toungni near Padcingon or Gwegyi. But my opinion is, that I do not believe that the occurrence of metallic gold at the outcrop of these lodes will continue to any great depth. Sooner or later it will disappear, and be replaced by undecomposed iron-pyrites. Then the difficulty of dealing with a "refractory" ore will have to be faced. This is the point which I want to put stress upon. We have, therefore, to answer the question: does the iron-pyrites contain a sufficient percentage of gold, so as to make its extraction a profitable business? This may be answered with *no*, as far as our present knowledge enables us to form a judgment. The richest ore contained a little over 4 dwt. of gold to the ton; but although as small a quantity as 3 dwts. is sufficient to pay some of the Australian mines, it is hardly beyond a doubt that in Wuntho the expenses will be too high to make gold-mining a payable concern, unless a higher percentage of gold to the ton of pyrites ore could be proved. I quite believe that should gold mining be really started some of the mines would pay a small dividend during a couple of years or so, but when the small supply of metallic gold, prepared in the chemical laboratory of nature, has been exploited, and when it comes to extract the gold from the pyrites, which holds it with an iron grip, every single one of the mining concerns will ingloriously break down. It may be argued that the natives have extracted gold at various localities in the Maingthong hill tract. True enough, and countless old and deserted diggings prove that they actually did, but it must not be forgotten that a native feels himself amply paid if he gets a few annas weight of gold after a month of hard work. The native does not employ expensive mechanical labour, and an equally expensive staff; a primitive pickaxe, a wooden shovel and a pan made on the spot, an ample supply of water is all he requires. With that outfit he sets to work, diligently, day per day; and when he thinks he has exhausted one place, he moves on to another. Small as his earnings may be there is no question that they sum up, if we suppose, that this work has been steadily going on for years and years. The gold which eventually comes to the market is perhaps the accumulated result of years of work. But if the same quantity were to be obtained within a short period of time, the working expenses would simply be higher than the value of the gold extracted.

2. *Argentiferous Cerussite.*—The results of the analysis prove that this is a highly valuable ore, and so far as I have observed there is a large quantity still available, but as I have already said, it must remain doubtful whether under the present conditions of railway communication and costly labour these ores could be worked profitably.

3. *Coal.*—According to the analysis the coal is of good quality; but not largely in excess of that from Kabwet or the Chindwin. It is in fact up to the average coal from the Burmese Territories, which makes a fairly good fuel, provided there is a sufficient quantity of it. But so far my examination of several localities

where such coal exists, does not warrant a very hopeful view, and in fact, except at one or two places, the seams are of wretchedly poor quality, consisting chiefly of coaly shale.

4. *Salt.*—In conclusion I may mention in few words how the natives utilize the salt springs. I have already stated that these springs are almost always found along the stream beds; and the natives have overcome the difficulty of obtaining a strong brine for evaporation in a most ingenious way. A fairly sized log of wood is hollowed out in the centre, and driven into the bed of the stream over the spring, whilst the space between this hollow cylinder and the rock is safely plugged with clay. A bamboo-wicker work is then placed round the wooden cylinder and the space between the two filled with clay, well rammed in; a few heavy boulders, on the top protect the clay from being washed away. The brine then rises in the wooden tube sometimes above the level of the surrounding stream. It is pumped out in the ordinary way by means of a pot, and then boiled down, in the way as described by me in a previous note on a salt spring near Bawgyo in the Shan States.

Preliminary notice *on the* Echinoids *from the* Upper Cretaceous System of Baluchistán, *by* FRITZ NOETLING, Ph.D., F.G.S., *Palæontologist, Geological Survey of India.*

The fine collection of fossils, which Messrs. Griesbach and Oldham have obtained from the cretaceous rocks of Baluchistán, contains, amongst others, numerous well-preserved *Echinoids*, several of which I recognised to belong to the genus *Hemipneustes* Agass. The occurrence of this genus seemed to indicate the existence of the étage *Danien* in Baluchistán--a fact which, if proved with certainty would be of considerable interest. The closer examination of the *Echinoids* has elicited some more interesting facts, which I publish now, because a considerable time must lapse before the examination of the whole fauna can be completed.

It is unfortunate that no figures of the new species can be given here, and, for the time being, the conclusions I base on the species mentioned below must be accepted in good faith, but I hope that the publication of the whole of the cretaceous fauna of Baluchistán will not be delayed much longer. On the other hand, I think that the results of the examination of the *Echinoids* will be of some assistance to the field geologists who are working now in Baluchistán, and it may be hoped that these notes will help to elucidate further facts concerning the development of the Upper Cretaceous system in Baluchistán.

From a paper in the "Records"[1] it appears that Mr. Oldham divides the strata below the Gházij beds (Eocene) into three groups, which in descending order are as follows:—

3. Dunghan group.
2. Belemnite beds.
1. Massive limestone.

An unconformable break is said to exist just above the Belemnite beds. It might then be expected that a considerable difference in the fauna of the Belemnite

[1] Geology of Thal Chotiali, Records, Geological Survey of India, Vol. XXV., P. 18.

beds and the Dunghan group would be met with, a view which had been fully borne out by the facts. However, Mr. Oldham, unfortunately, was led into a mistake, further elaborated in the 2nd Edition of the "Manual," p. 291, to assume that the Dunghan group contained an anomalous fauna, and that *Nummulites* were associated with cretaceous forms.

Mr. Oldham continues: "Under these circumstances it must remain an open question whether we are to regard the Dunghan group as oldest tertiary or newest secondary in age . . . If the top of the Dunghan group represents the lower limit of the tertiaries, we have to acknowledge an extreme abundance of the genus *Nummulina* in beds of cretaceous age; if the bottom, then the *Ammonoidea* are represented in beds of tertiary age by several genera and species. A third interpretation is open, and probably it will prove the true one, that the Dunghan group represents the gap between the Secondary and Tertiary period in Europe."

Supposing Mr. Oldham's observations were correct, they would contain nothing new, because true *Nummulites* have been discovered in the Eastern Pyrenees in strata which have been considered by Mr. Seunes[1] as belonging to the étage *Danien*. These strata are said to pass gradually into limestones which contain large *Nummulites* (*N. perforata*).

It is to be regretted that Mr. Oldham advanced such far-reaching theories on palæontological evidence which cannot be considered as conclusive. I have examined the "*Nummulina*" of the Dunghan group in Mr. Oldham's collection, and have found that Mr. Oldham had mistaken a species of the genus *Orbitolites* for *Nummulina*, and as the form is a typical cretaceous genus, the anomaly disappears.[2]

Mr. Griesbach has lately been over the sections described by Mr. Oldham in the paper quoted, and has found that there are three distinct series of rocks represented in that part of Baluchistán; the lowest (Mr. Oldham's "massive limestone") contains a number of fossils, which I am now engaged in working out. I found that they chiefly belong to the genera *Macrocephalites*, Zitt., and *Perisphinctes*, Waag., and that several forms from Kach, such as *M. transiens*, Waag., and *M. polyphemus*, Waag., are represented amongst them. The "massive limestone" is therefore of jurassic age, and represents probably the Kelloway group.

Above the massive limestone follows a series of beds, which are distinguished by an abundance of specimens of *Belemnites*. Locally the *Belemnite* beds may be divided into various horizons, but it seems doubtful whether such horizons could be traced over more than a very limited area. The examination of these forms has proved, that the Belemnite-beds must be considered to be of Neocomian age.

Above the *Belemnite* beds follow the calcareous beds (locally often sandstones) which contain a rich fauna, amongst which the genera *Sphenodiscus*, Zitt., and *Orbitolites*, must be specially mentioned. These beds are also characterised by the widely distributed *Cardita beaumonti*, D'Arch., which in Sind also occurs in the uppermost Cretaceous.

[1] Seunes, Observations sur le Crétacé supérieur des Pyrénées occidentales. Bull. de la Soc. Géol. de France, 3rd ser., vol. xvii, p. 803.

[2] I need not dwell here on the controversy that has been going on for a long time regarding the age of Leymerie's étage Garumnien. It is sufficient to say that Mr. Leymerie tried to explain the presence of cretaceous Echinoids in the calcaires à *Micraster tercensis* by the theory of colonies—a view which might also be applied to the Dunghan group supposing the anomalous fauna existed.

Above the dark-brown *Sphenodiscus* beds follows the white limestone of the Eocene formation with true *Nummulites.*

From the foregoing remarks it seems clear that the *Sphenodiscus* beds represent that part of Mr. Oldham's Dunghan group which contains the cretaceous fauna together with the so-called "*Nummulina.*"

The Echinoids which have been described in the following pages have been collected by Messrs. Griesbach and Oldham in the *Sphenodiscus* beds; none come from the massive limestone or the *Belemnite* beds, nor from the nummulitic limestone above. We are therefore in a position to ascertain with great accuracy the age of the *Sphenodiscus* beds.

The Echinoid fauna here described consists of 11 genera with 16 species, of which 8 genera are represented by one, three genera by two, and one genus by three species, *viz.* :—

1. *Cidaris suleimani*, spec. nov.
2. *Orthopsis perlata*, spec. nov.
3. *Cyphosoma sp.*
4. *Protechinus paucituberculatus*, gen. et spec. nov.
5. *Echinoconus gigas*, Cotteau.
6. *Holectypus baluchistanensis*, spec. nov.
7. *Pyrina ataxensis*, Cotteau.
8. „ *gigantea*,[1] spec. nov.
9. *Echinanthus griesbachi*,[1] spec. nov.
10. *Clypeolampas helios*,[1] spec. nov.
11. „ *vishnu*, spec. nov.
12. *Hemipneustes pyrenaicus*, Hébert.
13. „ *leymeriei*,[1] Hébert.
14. „ *compressus*, spec. nov.
15. *Hemiaster blanfordi*, spec. nov.
16. „ *oldhami*, spec. nov.

Out of the 16 species, 15 have been determined specifically, and only 1 generically; out of the 15 specifically determined species, 11 have been found to be new, but 4 could be identified with well-known species from Europe; these are—

Echinoconus gigas, Cotteau.
Pyrina ataxensis, Cotteau.
Hemipneustes pyrenaicus, Hébert.
„ *leymeriei*, Hébert.

I wish to say at once that among the 11 new species several show so close a relationship to other European species that it is quite probable that on actual comparison with the type specimens they may be found identical, and that the number of European species appearing in the cretaceous system of Baluchistán may in fact be much larger than stated above. However, the four species named have been recognised with great certainty, and we may therefore say that the Echinoid fauna of Baluchistán exhibits a most marked European character.

[1] The horizon of this species is not quite certain; Mr. Oldham, who has collected it, simply states from "Dunghan group"; from the state of preservation I think that it has been collected in argillaceous strata just above the *Belemnite* beds.

This feature appears still more remarkable if we take into consideration that these four species occur principally in the étage *Danien* of the Pyrenees. We are therefore fully justified in assuming, from the evidence of the Echinoids, that the cretaceous fauna of Baluchistán is of European type, and showing the closest relationship with the cretaceous fauna of the étage *Danien* of the Pyrenees. I admit that this is a somewhat startling result, and I must say that for some time I felt serious doubts as to its correctness, considering the great geographical separation; but after I noted down this fact, I came across Mr. Cotteau's note, "Sur un exemplaire du *Coraster Vilanovæ* provenant de Tersakhan (Turkestan)."[1] Mr. Cotteau, whose high authority on Echinoids will hardly be doubted by anybody describes in this a small echinoid, which had been presented to his brother by General Komaroff of the Russian Army. I quote here Mr. Cotteau's own words:—

"Cette espèce avait été dans l'origine considerée par M. Vilanova et par moi qui n'avais fait que suivre ses indications, comme éocène. De nouvelles observations ont demontré que la couche qui renferme le *Coraster Vilanovæ* doit se placer dans la Craie, à un niveau supérieur. La découverte de cette espèce faite récemment par M. Seunes dans la Craie supérieure des Pyrénées, ne laisse plus aucun doute sur l'horizon stratigraphique du *Coraster Vilanovæ*.

"La présence de ce petit Échinide, à une aussi grande distance des Pyrénées et de la province d'Alicante, est extrêmement intéressante et suffit pour établir que les dépôts de Tersakhan, dans lesquels il a été recueilli, font partie de la Craie supérieure, et que, suivant toute probabilité, les mers crétacés, qui recouvraient cette partie de la péninsule espagnol et des Pyrénées, se prolongeaient jusque dans le Turkestan."

There is other evidence of the probability that the cretaceous beds of Turkestán belong to the same area of deposition as those of Baluchistán, and if an Echinoid has been discovered in the former which is identical with a form which has hitherto only been found in the Upper Cretaceous system of the Pyrenees and Spain, it is by no means surprising that in Baluchistán several species have been found which are also identical with forms occurring in the cretaceous beds of the Pyrenees.

Mr. Cotteau's view that the sea in which the cretacous beds of the Pyrenees were deposited, extended to the Turkestán area, appears to be fully corroborated by the examination of the Echinoids from Baluchistán. In fact we might assume that the cretaceous sea in which this remarkable fauna lived had extended far to the south and certainly reached to Baluchistán.

If we turn our eyes further south-east and compare the Echinoids from the Arialoor group of Southern India with those from Baluchistán, we observe a most striking difference in the facies of the fauna and find that not a single species is common to both localities; in fact the whole composition of the Echinoid-fauna of Southern India differs greatly from that of Baluchistán, as will be seen from the following table. The following genera have been found in:—

	Baluchistán.	South-India.
Cidaris	X	X
Orthopsis	X	X
Cyphosoma	X	

[1] Bulletin de la Société Géologique de France, 3rd ser., Vol. XVII, p. 155.

	Baluchistán.	South India.
Pseudodiadema		X
Micropedina		X
Protechinus	X	
Salenia		X
Holectypus	X	X
Echinoconus	X	X
Nucleolites		X
Pyrina	X	
Cassidulus		X
Stigmatopygus		X
Botriopygus		X
Catopygus		X
Echinanthus	X	
Clypeolampas	X	
Hemipneustes	X	X
Holaster		?
Cardiaster		X
Epiaster		?
Hemiaster	X	X

We see, therefore, that out of a total of 22 genera which occur in the Arialoor group of Southern India and in the etáge *Danien* of Baluchistán, only five genera are common to both areas, namely,—

1. *Cidaris*,
2. *Orthopsis*,
3. *Holectypus*,
4. *Echinoconus*,
5. *Hemiaster*,

and probably also a sixth, the genus *Hemipneustes*; but the presence of the latter in Southern India is somewhat doubtful, because I base it on the supposition only that the ill-preserved *Cardiaster orientalis*, Stol., does not belong to that genus, but to *Hemipneustes*, as its poriferous zones indicate. Of the above-named five genera, four, *Cidaris*, *Hemiaster*, *Holectypus*, and *Echinoconus* are widely distributed genera, from which no conclusion can be drawn, and only *Orthopsis* may be said to be limited in its vertical distribution, and this genus, together with the probable *Hemipneustes*, would form the only connective links between Echinoid fauna of the upper cretaceous beds of Southern India and Baluchistán.

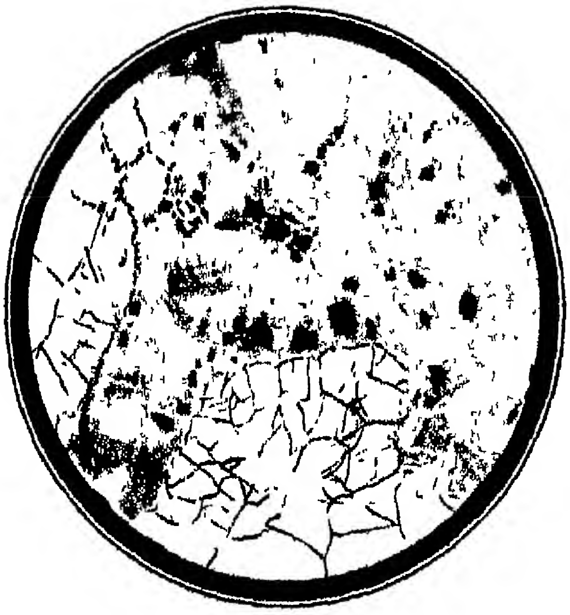
It may, however, be remarked that it would have first to be proved that the Arialoor group could be correlated with the *Sphenodiscus* beds in Baluchistán, before a comparison of their respective Echinoid fauna could be undertaken; in fact it might be assumed that such comparison is inadmissible if, as it is supposed, the Arialoor group represents the etáge *Senonien* in Southern India, whilst the *Sphenodiscus* beds can be correlated with the etáge *Danien*.

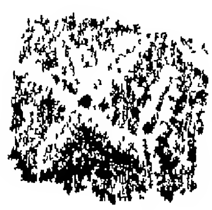
Mr. Lévillé,[1] however, has recognised the presence of the etáge *Danien* in Southern India, which he calls Ninyur group, and of which we must suppose that it was included in the Arialoor group, and therefore a comparison of the *Danien* in Baluchistán with the Arialoor group of Southern India may by no means be incompatible with the actual facts.

It must therefore be admitted that a large faunistic difference exists in the

[1] Bulletin, de la Société Géol. de France, 3rd ser., Vol. XVIII, 146.

T H Holland





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Echinoid faunas of the upper cretaceous systems of Baluchistán and Southern India—a difference which not only concerns the species but also the genera. This fact is the more striking if we consider the faunistic similarity between the upper cretaceous systems of Baluchistán and the Pyrenees.

The only inference which we are able to draw from this fact is that a great faunistic province extended from South-Western Europe towards Central Asia and Baluchistán—the cretaceous Mediterranean Sea,—and that this same province was separated by a land barrier from the sea, in which were deposited the cretaceous beds of Southern India; a view which has already been expressed by other writers, amongst them the late Dr. Neumayr.

On Highly Phosphatic Mica-Peridotites intrusive *in the* Lower Gondwana Rocks *of* Bengal, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

1. Besides the fact that hitherto only one or two types of ultra-basic rocks have been described in India, a special interest attaches to the varieties of the rock described in this paper for the following reasons :—

1st.—It is irrupted as dykes and sheets coking the coal and baking the sandstones and shales of Damuda age in Bengal, thus occupying a position similar to that of its near relative, the diamond-bearing peridotite of South Africa, which breaks through the carbonaceous rocks of the Ecca beds and Kimberley shales—strata contemporaneous in geological age and agreeing partly in lithological characters with the coal-bearing Damuda series of India. That diamonds have originated by the action of peridotites on carbonaceous rocks seems to be a most natural conclusion from their frequent occurrence either in the igneous rock itself (South Africa), or in localities where peridotites are intruded into carbonaceous rocks (New South Wales, Western America). This similarity of conditions, therefore, in the Indian coal-fields is most suggestive.[1]

2nd.—The presence of biotite and anthophyllite amongst the leading constituents of this rock considerably limits the number of its relatives amongst the described peridotites of the world, whilst the quantity of apatite, amounting sometimes to over 11 per cent., makes it unique amongst igneous rocks. Whilst apatite is about the most widely distributed of all rock-forming minerals, I know of no case in which its proportion amongst the rock-constituents would entitle it to be regarded other than as an accessory, whilst in the peridotites it is comparatively scarce.

2. Mr. F. G. Brook-Fox called my attention to these rocks in 1892, and kindly brought specimens from Giridih and Assensole. Since that date I have followed up the subject during short holiday excursions to the coal-fields, principally in company with Dr. Saise, Manager of the East Indian Railway Company's collieries at Giridih, to whom I am indebted for some very interesting specimens and for generous assistance in many ways. I am indebted also to Professor Judd of the Royal College of Science, London, for having kindly examined the slides of the mica-peridotites from the Darjiling area and for correcting my determinations.

[1] *Cf.* H. Carvill Lewis, "On a diamantiferous peridotite and the genesis of the diamond," *Geol. Mag.*, dec. III, vol. IV (1887), p. 22; *Rep. Brit. Ass.*, 1887, p. 720. A. H. Green, "A contribution to the geology and physical geography of Cape Colony," *Quart. Journ. Geol. Soc.* vol. XLIV (1888), p. 239. The diamond-bearing peridotite of South Africa is, like the Bengal rock, associated with a series of intrusive sheets and dykes of dolerite, which appear to be the underground representatives of the great sub-aërial lava-flows forming the highest sub-division of the Stormberg beds (Green, *loc. cit.*, p. 255), and thus occupying a position corresponding to the Rajmahal traps of Bengal.

The analogy of the occurrence of diamonds in meteorites and in peridotites, their nearest terrestrial allies, has frequently been remarked (*vide* Daubrée, *Comptes Rendus*, vol. CX (1890), p. 18).

II.—PREVIOUS DESCRIPTIONS OF THE "MICA TRAPS."

3. Dr. W. T. Blanford seems to have been the first to record the occurrence of black mica in the dykes of igneous rock intersecting the Lower Gondwana beds of the Raniganj area, and although in 1860 he could have had no means for distinguishing the petrological characters of the two principal types of dyke-rocks intrusive in the coal-field, he distinguished two groups by their distribution amongst the stratified rocks, describing what he thought to be the older as almost invariably decomposed and soft, forming a red or yellow stone, frequently vesicular and with a habit of forming sheets in the coal and sandstones. From observations which have been greatly facilitated by mining operations since carried out in this and in the adjoining coal-fields, I find that the dykes which are soft, buff-coloured and vesicular at the surface can be traced in the mine-shafts to compact mica-apatite-peridotites, whilst the basaltic dykes, which can now be proved to be younger (*vide infra*, paragraph 14), display characteristic jointing and spheroidal weathering at the surface, with microscopic characters that are unmistakeable.[1]

4. In 1866 Mr. Hughes distinguished the mica-traps, which decomposed to yellow earth and occurred in narrow dykes in the Jherria coal-field, from the basaltic dykes of the same area.[2]

5. In 1867 Dr. V. Ball described a trap-dyke, crossing the Dámodar (Dámuda) north-east of Burobing in the Rámgarh coal-field, as decomposed and earthy similar to many seen in the Ráníganj field.[3]

6. In 1868 Mr. Hughes recognised micaceous traps amongst the dykes of the Girídíh (Karharbárí) coal-field.[4]

7. In the Jaintí coal-field (Deoghur) Mr. Hughes distinguished in 1868—70 between the micaceous and the augitic types of dyke-rocks, remarking that the former are always in thin dykes, are more decomposed, and affect the sedimentary rocks to a greater extent than the latter—an observation which is confirmed by a microscopic study of the contact effects.[5]

8. The first microscopic examination of the so-called "mica-traps" was made in 1880 by Mr. F. Rutley of the Royal College of Science, London, who described specimens collected in the Girídíh (Karharbárí) coal-field by Dr. Saise. According to the extract from Mr. Rutley's note published in Dr. Saise's paper on the coal-field, the rocks were "micaceous traps very decomposed indeed, the felspar being replaced by carbonate of calcium." In one specimen he suspected the occurrence of olivine.[6]

9. In 1888 my colleague, Mr. P. N. Bose, described some mica-traps from Bara-

(1) "On the geological structure and relations of the Raniganj coal-field, Bengal." *Mem. Geol. Surv., Ind.*, vol. III, pp. 141—149. The great Salma dyke, for instance, to which Dr. Blanford referred as possibly a member of the younger group (p. 143), is an augite-plagioclase rock.

[2] *Mem., Geol. Surv., Ind.*, vol. V, p. 322.

[3] *Ibid.*, Vol. VI, p. 129.

[4] *Ibid.*, Vol. VII, p. 239. Recently these and the other dykes of this area have been examined in detail by Dr. Saise and myself and will form the subject of a separate note.

[5] *Mem., Geol. Surv., Ind.*, Vol. VII, p. 252.

[6] *Trans. North Eng. Inst. Min. and Mech. Eng.*, Vol. XXX (1880), p. 13.

kar and Ránīganj under the names *kersanton* and *kersantite*.[1] From an examination of Mr. Bose's slides and specimens, together with a large collection of fresher rocks from this and other coal-fields in Bengal, I should not hesitate to class these rocks with a far more basic type.

III.—MODE OF OCCURRENCE.

10. Compared with the basaltic dykes of the same area, the mica-peridotite intrusions are very narrow, never, so far as seen in the Girídíh coal-field, exceeding about 3 feet in width; and this seems to be true also of similar intrusions in the associated fields.[2] From dykes of this width it can be traced down to minute veins ramifying in the most intricate manner, and even as thin films spreading between the separate columns in the zones of burnt coal which border the dykes (6·930).[3]

11. This rock frequently occurs also as sheets intruding along the beds of coal-bearing rocks—a habit noticed by Dr. Blanford to be so constant that he found it necessary to reassure himself that the igneous rocks were not interstratified lava-flows contemporaneous with the coal.[4] It has thus become to the coal-mine owners a more formidable pest than the larger masses of basalt which occur in vertical dykes.

12. A further mode of occurrence is exhibited in one of the mines of the East Indian Railway Company's collieries in the Girídíh field (Jogtínd shaft, No. 7). One of the galleries has been driven through a mass of peridotite 50 feet thick, and numberless veins from this are found ramifying in all directions and anastomosing amongst the coal-seams around. The other galleries of the mine have, however, only passed through narrow dykes of trap, and they show that the lateral limits of the large mass are, at any rate, within the area of the galleries. There is, therefore, a boss-like expansion in this locality.

13. Representatives of the same rock, with slight local variations in structure and mineral composition, occur in the coal-fields of Ránīganj and Barákar, of Jherria, of Deoghur, and probably of Rámgarh. It occurs also in the Darjiling coal-field also in sheets, with the usual contact-effects of intrusion.

Geological age.

14. According to Dr. Blanford, there is a much larger amount of trap permeating the Lower Damudas than the younger beds, and the sheets of igneous rock intruded into the former strata appear to be alone amongst the trap-rocks of the field which have been thrown by faults. The age of these rocks is, therefore, given as probably Damuda and possibly Lower Damuda.[5] Specimens which I identify with the mica-peridotite here described were collected by Mr. Bose and stated by him to be intrusive in the Raniganj series.[6] The uppermost members of the

[1] *Rec., Geol. Surv., Ind.*, Vol. XXI (1888), p. 163. See also description of the mica-traps occurring in the Damuda rocks of Darjeeling district. *Ibid.*, Vol. XXIII (1890), p. 241.

[2] For example, Jherria (Hughes), Jainti (Hughes), and Raniganj (Blanford).

[3] The numbers in parenthesis refer to the specimens in the Geological Museum, Calcutta, which illustrate the features described or figured in this paper.

[4] *Loc. cit.*, pp. 146 and 147.

[5] *Loc. cit.*, pp. 148 and 149.

[6] *Rec., Geol. Surv., Ind.*, Vol. XXI (1888), p. 164. (Specimen No. 8·283).

Damudas, therefore, must be fixed as older than this intrusion. In a paper by Dr. Saise and myself which is in course of preparation, it will be shown that the mica-peridotite is, as Dr. Blanford suggested from more indirect evidence, older than the associated basaltic rocks, and if we take these (as all later workers have agreed with Dr. Blanford) as contemporaneous with the Rajmahal lava flows, the age of the mica-peridotite can be fixed between the narrow limits of Damuda on the one side, and Rajmahal on the other, that is to say, not far from the Trias of Europe and the Panchet of India.

Contact effects.

15. Wherever the peridotite has invaded the coal-measures the *coal* has lost its lustre, is heavier, hardened, coked and often made beautifully columnar in zones of variable width along both sides of the dykes.

In an equally striking manner *sandstones* have been baked and even partially fused, with the production, in the more felspathic kinds, at structures which sometimes recall the corroded quartz-crystals and crypto-crystalline fluidal matrix of a rhyolite. These contact-effects will be described in detail in the joint paper already referred to.[1]

IV.—PETROLOGICAL CHARACTERS.

Macroscopic characters.

16. The most coarsely-grained varieties have been obtained in the Darjfling district. In specimens of these the glistening scales of brown mica measuring about 2 mm. across form the most prominent feature (8·723, 9·707). The freshest specimens have been obtained from Giridih, and appear as tough and almost black rocks with spangles of biotite, glassy-looking phenocrysts of olivine, and large numbers of acicular crystals of apatite (9·876). Specimens from the narrower dykes and veins are generally dark green in colour, finer in grain, and are always more decomposed, masses of serpentine representing the original phenocrysts of olivine (9·104). In small veins and on the selvages of larger intrusions the rock is compact, of a greenish tinge, weathering to a buff-coloured earth (9·1044, 9·1045). Sometimes the selvages present a variolitic appearance, but the structures which represent the original varioles are now made up of secondary minerals. A similar variolitic appearance has been recorded by Diller at points where in the peridotite of Elliott County, Kentucky, the rock comes in contact with the strata and includes fragments of shale.[2] (See also para. 35.)

17. Where in breaking through the coal the rock has met a nest of iron-pyrites there has been produced a slaggy mass with very distinct fluidal structure and

[1] The late J. B. Jukes, referring in the memoir on the South Staffordshire coal-field to the distances to which the narrow veins of igneous rocks run in the coal-measures of that area, concludes that "at the time of the injection it had a temperature not merely just sufficient to melt it, but a much higher one, sufficient to allow of the loss of a considerable quantity of heat, and yet for the matter to remain still molten in its passage to very considerable distances from the volcanic focus" (2nd edition, (1859), p. 123). I have referred above (para. 10) to the fine ramifications and the long, yet narrow, dykes of mica-peridotite in the Bengal coal-fields, and the conclusion that such a condition is indicative of high temperature is confirmed by the intensity of the widely-extended results of contact metamorphism noticed by Dr. Blanford.

[2] *Bull., U. S. Geol. Surv.*, No. 38 (1887), p. 23.

black colour, like the artificial slags darkened by sulphides described by Percy (9·877).[1]

18. In some cases, where the biotite occurs in excessive proportions, the result of pressure at the margins of the dykes has given rise to a rock as fissile as mica-schist (9·1047).

19. At the surface the dykes weather to a soft buff-coloured earth in which the partially bleached and hydrated mica frequently appears, as noticed by Dr. Blanford, wrapped around small spheroidal masses, which are often hollow in the centres and remind one again of varioles (9·874). In these weathered specimens bands of cavities strongly resembling those of a scoriaceous lava frequently occur; they are presumably only hollows from which serpentine and other minerals have been removed in solution (9·872).

Specific gravity.

20. As all specimens have suffered to some extent from hydration the specific gravity of the rock has been lowered to varying degrees. The following table shows the average specific gravity of the principal types:—

	Rock.	Sp. Gr.
9·876.	The freshest specimen with porphyritic olivine, from the centre of the large mass in No. 7 Jogitand shaft, Giridih. Depth, 286 ft.	2·99
8·723.	Coarse-grained variety from the eastern branch of the Cherang Khola, Darjiling district	2·90
9·105.	Fine-grained rock with olivines completely decomposed. Dyke in No. 7 Jogitand shaft, Giridih	2·80
9·104.	More decomposed and finer in grain. Same locality	2·71
9·199.	Buff-coloured and soft decomposed variety from the dyke at the surface	2·684

Fusibility.

21. Specimens, like 9·105, in which the olivines have been hydrated into serpentine, fuse easily before the blowpipe to a black, non-magnetic, and slightly vesicular glass (degree 3 of von Kobell's scale). The fresher varieties containing clear olivine are more refractory—a difference evidently due to the contained water whose influence on the fusibility of substances is well-known from the results of the late Prof. Guthrie,[2] whilst Prof. Judd, with these researches in mind, has pointed out that rock-masses heated to within a small range of their fusion points when dry may become molten on the introduction of water.[3]

22. Fragments of a partly decomposed variety fused for five minutes in a crucible gave on cooling a streaky bronze-coloured glass, which was easily decomposable by hydrochloric acid, and had a specific gravity of 2·895, being thus heavier than the original rock (2·80).

23. The glass kept at a cherry-red heat for 12 hours, lost its vitreous lustre and darkened in colour, resembling tachylyte. The fracture at the same time became "uneven," and the specific gravity rose to 2·99, whilst the product was far less easily decomposed by acid than the original glass.

[1] Metallurgy (Fuel), 1875, p. 58.
[2] *Phil. Mag.* vol. XVIII (1884), p. 117.
[3] *Geol. Mag.*, dec. III, vol. V (1888), p. 10.

24. Under the microscope the glassy form has a yellowish brown colour with feathery skeleton crystals generally developed around nuclei of magnetite. The partly devitrified form, however, is so crowded with such feathery skeleton-crystals that they interfere with one another during growth. These microlites are colourless in their centres, possess a high index of refraction, high double refraction, and in shape resemble those of olivine.[1] (Plate I, fig. 5.)

Chemical composition.

25. All but the freshest specimens effervesce with mineral acids, and the microscope confirms the presence of rhombohedral carbonates (paragraph 36). It seems natural to expect that slow oxidation of the coal by oxygen dissolved in the circulating under-ground waters would result in the production of considerable quantities of carbonic acid and consequent formation of carbonates from the decomposing silicates of iron, lime and magnesia. A similar phase of alteration seems to have been noticed in most cases of igneous rocks which have intruded into coal measures.[2]

Of specimen No. 9·876 as much as 58·23 per cent. was *soluble* in hydrochloric acid.

26. A remarkable feature of the rock is the large quantity of *phosphoric acid*, which the microscope shows to be in the form of apatite (Plate I, figs. 1, 2 and 3). Specimen No. 9·876 yielded 5·234 per cent. P_2O_5 (equivalent to 11·426 per cent. $Ca_3 P_2 O_8$), whilst the analysis of a more hydrated form (9·105) from the same shaft, gave phosphoric acid equivalent to 10·66 per cent. of lime phosphate. The decomposition of large quantities of this rock at the surface must contribute sensibly to the fertility of the neighbouring soil; but though the quantity of lime phosphate would be considered large enough to warrant remark from the petrologist, it would not be sufficient to justify raising for economic purposes. Even the richest form would be poor compared with the basic Bessemer slags, and the use of these has been attended with indifferent success.[3]

27. The proportion of *silica* rises not only by the removal in solution of the soluble bases, but in this case, where the rock invades masses of sandstones, fragments of quartz are caught up and infiltrations of silica would naturally be expected. The following results have been obtained :—

Nature of the rock.	Sp. Gr.	Silica per cent.
9·876. Olivines partly decomposed	2·99	40·25
9·105. Olivines completely hydrated	2·80	41·32
8·284. Rock much decomposed, with secondary quartz .	2·77	48·48[4]
8·283. Ditto ditto .	2·45	51·68[4]
8·282. Vesicular rock containing much secondary silica .	...	57·88[4]

[1] *Cf.* Rosenbusch, Micro. Phys. (Iddings) 1888, p. 213.

[2] *Cf.* Delesse, *Ann. des Mines.*, 5th ser. vol. XII (1857), p. 144 *et seq.* J. B. Jukes, *op. cit.*, p. 118. I. L. Bell, *Proc. Roy. Soc.*, vol. XXIII (1875), p. 547. J S. Diller, *Bull. U. S. Geol Surv.*, No. 38 (1887), p. 19. E. Stecher, *Tschermak's Min. Mitt.*, vol. IX (1888), pp. 190, 195. also *Proc. Roy. Soc. Ed.*, vol. XV (1888), p. 172.

[3] Wedding, Basic Bessemer Process, Eng. Ed. (1891), p. 172.

[4] Analysed by Mr. T. R. Blyth; Bose, *Rec., Geol. Surv., Ind.*. vol. XXI., pp. 164 and 165.

Microscopic characters.

28. The numerous specimens which have been collected from different parts of the coal-fields exhibit a wide variation in structure and, within small limits, a variation in mineral composition. There is no difficulty in recognising the fact that the selvages of the dykes are finer in grain than the portions nearer the centres, and that the middle portions of the larger masses are more perfectly crystalline than the smaller veins which branch from them. But, as the face of a dyke is generally a plane of water circulation, the selvages and—for the same reasons—the smaller veins have been in all cases much decomposed, with the destruction of the glass which was very probably amongst the original constituents. (See para. 35.) With the exact knowledge, however, obtainable from the undecomposed types there is little chance of error in identifying the shapes of minerals whose places have, since consolidation, been filled with such secondary products as quartz and rhombohedral carbonates.

Minerals.—The minerals which enter into the composition of these rocks are as follows:—

Primary (approximately in order of crystallization).—

- Apatite.
- Olivine.
- Spinelloid iron-ores (Magnetite, Chromite) and Ilmenite.
- Biotite.
- Anthophyllite
- Augite.
- Doubtful matrix in small quantities.

Secondary—

- Serpentine.
- Magnetite.
- Perofskite.
- Rhombohedral carbonates, chiefly dolomite.
- Hydrated oxides of iron and clay.
- Pyrites.

Primary minerals.

29. *Apatite* (Plate I, figs. 1, 2, and 3) occurs in slender prisms sometimes 3 mm. long and seldom measuring more than 0·15 mm. across. Basal sections are hexagonal in shape with sharp angles, exhibiting undoubted isotropism. The centres are often darkened by numerous cavities disposed parallel to the vertical axis and sometimes arranged in zones (9·105). Occasionally, however, the apatites are free of such inclusions (9·876, 8·723). Longitudinal sections are jointed transversely, and show low double refraction polarising in characteristic greys, with unmistakeable straight extinction. The quartz-wedge plainly shows the negative character of the double refraction.

Treated with hydrochloric acid the crystals are dissolved, leaving empty spaces on the slide; the solution readily gives a yellow precipitate with ammonic molybdate.

Apatite occurs only in comparatively small quantities in the Darjiling specimens (8·723) and is most conspicuously developed in those from Giridih (9·104, 9·105, 9·876), amounting to over 11 per cent. of the rock. It withstands decom-

position longer than any of the constituents of the rock except biotite, and is found in scattered needles in specimens in which the olivines have been completely replaced by carbonates (9·877).

Apatite as usual is included by all other constituents, but most rarely by the olivines. The excessive quantity of this mineral in view of previous descriptions of igneous rocks, and especially of peridotites, certainly seems surprising; but chemical analysis so completely confirms the microscopic characters that there is no question of its identity,[1] I have considered it necessary to give these details because this mineral has, apparently, been taken for plagioclase. Mr. Bose, whilst omitting to mention the presence of apatite in specimen No. 8·283, has referred to "lath-shaped, badly-developed crystals of plagioclase occurring as individuals and exhibiting no twinning."[2] On examination of the original slide I should not hesitate to identify these crystals with apatite, whilst there is no evidence now of the presence of plagioclase (slide No. 563).

30. *Olivine* (Plate I, figs. 1—4) occurs as large clear phenocrysts measuring sometimes as much as 10 mm. across (9·876), and as smaller crystals, which are almost always serpentinised. The crystals are well-shaped, and sometimes have sharp edges preserved. Serpentinous hydration has developed along the characteristically irregular cracks with separation of magnetite dust. A common occurrence is a more or less circular crack cutting off an exterior zone, which is cracked radially and into small fragments, from a central mass which is cracked more irregularly (fig. 4). The high refractive index and strong positive double refraction are those of olivine. Cleavage is sometimes developed parallel to the brachy-pinacoid as shown by the position of the interference figure in macro-pinacoidal sections. Pieces taken from the clear porphyritic crystals sank in a liquid of specific gravity 3·30. In a few types olivine still remains fresh (8·723, 9·707, 9·876), but most specimens show either complete conversion into serpentine (9·105) or final replacement by rhombohedral carbonates (8·283), sometimes with secondary quartz (9·877).

31. *Iron-Ores (Magnetite, Chromite) and Ilmenite* (figs. 1—3).—These are very variable in development. In the Darjfling specimens they are either absent or rare as primary constituents (8·723 and 9·707). In some Girfdih specimens they occur in numerous well-shaped crystals included in the biotite, but not in the olivine or apatite. Some of these granules transmit light of a brown-yellow colour, possess a high refractive index, and are isotropic. As this rock gives decided reactions for chromium, it is more than likely that these grains are chromite, which is so characteristic of ultra-basic rocks.

[1] Mr. Harker in describing recently the gabbros of Carrock Fell has made the interesting observation that whilst apatite is scarcely to be found in most specimens of the more acid varieties of the gabbros it becomes locally abundant in the highly basic marginal rocks. (*Quart. Journ. Geol. Soc.*, vol. L (1894), p. 324, and plate XVII, fig. 4).

A concretionary substance infilling joints and cracks in a compact peridotite from St. Paul (Atlantic) contained considerable quantities of phosphate of lime, but Renard concluded that it was formed after the manner of common mineral incrustations and is, therefore, not comparable to the large quantities of apatite which exists as a rock-forming mineral in the Bengal peridotites under consideration ("Challenger" Reports. Narrative, Vol. II, Report on the Petrology of the rocks of St. Paul (1879), pp. 16 and 21).

[2] *Rec., Geol. Surv., Ind.*, vol. XXI (1888), p. 165.

32. *Biotite* (figs. 1 and 2) is preserved in all but the most decomposed varieties. The pleochroism is very striking, changing from deep red-brown to bright yellow. Numerous inclusions of apatite and olivine sometimes give the crystals an ophitic aspect (9·105), but occasionally clear crystal-outlines are noticeable (9·707). The small optic axial angle is noticeable in basal scales.

33. *Anthophyllite* (fig. 2).—In the Darjiling specimens, and to a less extent in some from Girîdîh (9·104, 9·105), there occur platey or divergent bundles of a mineral exhibiting most striking pleochroism. Cross-sections of these show prismatic cleavages like those of amphibole, and I am indebted to Professor Judd for calling my attention to the way in which these features can be paralleled amongst the anthophyllites. Between crossed Nicols sections show colours always of a lower order than the neighbouring olivines, whilst longitudinal sections show straight extinction. Partial interference figures are obtained in the longitudinal sections which show pleochroism from deep claret-red to gamboge-yellow. From these the double refraction appears to be negative. Other longitudinal sections showing pleochroism from straw-yellow to gamboge-yellow never give an interference figure in convergent polarised light. The crystallographic relations of these features can be made out from the cross-sections, which show the characteristic amphibole cleavage: in these the pleochroism is claret-red (rays vibrating parallel to the macro-diagonal) and straw-yellow, (rays vibrating parallel to the brachy-diagonal). We see, therefore, that the rays vibrating parallel to the vertical axis, as shown in the longitudinal sections, are gamboge-yellow, and as the interference figure is obtained only in the sections which show the claret-red to gamboge-yellow pleochroism the optic axial plane must be parallel to the brachy-pinacoid, and, the double refraction being negative, we have the following optical scheme:—

$a = \mathfrak{a}$, straw-yellow.
$b = \mathfrak{b}$, claret-red. *Absorption*, $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$.
$c = \mathfrak{c}$, gamboge-yellow.

The crystals are frequently marked by bands of fine cavities which can only be individualised under 1-8th inch objective. Along the edges and into cracks there is generally a bluish green fringe which seems to be a change to chlorite, polarising with very much lower colours. The grains were too small and too well intergrown with other minerals to permit isolation of pure material for chemical analysis; but from the properties which can be tested it seems safe to refer this mineral, as Professor Judd has suggested, to the group of rhombic amphiboles. Anthophyllite is, according to Rosenbusch, often found in serpentines.

34. *Augite* (fig. 2) occurs in colourless or pale green crystals often developed around biotite. It occurs in the Darjiling rocks in very small quantities, and its intimate association with the amphibole suggests an origin for the latter. In the Girîdîh specimens its distribution is variable. It occurs with the anthophyllite sometimes in considerable quantities (9·105), and sometimes is absent in specimens obtained from the same shaft; in this case it is noteworthy that the amphibole is at the same time wanting (9·876). Unless represented by the microlites of the groundmass it is absent also from the more compact varieties (9·109).

35. *Matrix* (fig. 2).—In addition to the minerals described above, there occurs in the Girîdîh specimens a dirty matrix polarising with very low tints, either in small irregular patches like a partly devitrified glass, or as a microcrystalline mosaic. In

some places it suggests felspar, but there are no signs of twinning or definite crystal structures and its quantity is very small. It appears like a residuary matrix (9·876, 9·105). Classing this substance as an altered glassy matrix seems to be the more justified from the occurrence in the American mica-peridotites of a glass presenting similar characters. In a mica-peridotite occurring as a dyke of late carboniferous age in Central New York C. H. Smyth, Jr., has recognised a glassy matrix which is not always devitrified.[1] A brownish-grey clouded material with similar relations has been noticed by Diller in a mica-peridotite dyke in Kentucky,[2] and similar material has been found in other peridotites, for example, in kimberlite from South Africa (H. Carvill Lewis) and in the Elliott county peridotite in Kentucky (J. S. Diller).

Secondary minerals.

36. In all specimens the processes of hydration and the production of carbonates have commenced. *Serpentine,* as usual, results from the hydration of the olivine, the change being attended with the separation of dusty *magnetite.* In one specimen in which decomposition has well advanced small crystals imbedded in the serpentine exhibit the characters of *perofskite.* They occur as yellow, clouded grains generally diamond or spindle-shaped, measuring up to 0·1 mm. long and 0·05 mm. wide. The grains when sufficiently clear to examine with polarised light show occasionally very strong double refraction which seems to be due to carbonates filling the yellow shells. When quite brown, however, they are isotropic. Removed from the serpentine with a sharp needle and fused with sodium-carbonate they gave a distinct reaction for titanium on being boiled with hydrochloric acid and tin. Diller has described as anatase similar grains in the serpentine pseudomorphous after olivine in the peridotite of Elliott County, Kentucky. G. H. Williams identified perofskite in the serpentine of Syracuse, New York in 1887,[3] and at his suggestion Diller on re-examining the Elliott Country peridotite found that similar grains which had been doubtfully referred to anatase were really perofskite.[4] Similar grains in peridotites have been referred to perofskite by C. H. Smyth (Central New York),[5] by Diller (Kentucky)[6] and by Branner and Brackett (Arkansas).[7] The *carbonates,* which are so common in these rocks, give the chemical reactions for dolomite.[8] These are found, sometimes with clear *secondary quartz,* infilling cavities from which decomposable minerals have been removed. As a final stage in the processes of decomposition, the magnetic oxides

[1] *Amer. Journ. Sci.*, 3rd Ser., Vol. XLIII (1892), p. 324.
[2] *Ibid*, 3rd Ser., Vol. XLIV (1892), pp. 287 and 288.
[3] *Ibid*, 3rd Ser., Vol. XXXIV (1887), p. 140.
[4] *Ibid.*, 3rd Ser., Vol. XXXVII (1889), p. 219.
[5] *Ibid.*, Vol. XLIII (1892), p. 324.
[6] *Ibid.*, Vol. XLIV (1892), p. 287.
[7] *Ibid.*, Vol. XXXVIII (1889), p. 57.
[8] Previous records of the occurrence of carbonates among the secondary products of igneous rocks which have intruded into carbonaceous strata have already been referred to (*ante*, p. 135). In the case of the Elliott Co. peridotite similarly situated, the carbonate was found also to contain magnesia (Diller, *loc. cit.*, p. 19). For further development of dolomite from peridotite, see Wadsworth, Lithological studies, *Mem. Mus. Comp. Zool. Cambr. Mass.*, Vol. XI (1884), p. 139, and R. D. Irving, Fifth Ann. Rep., U. S. Geol. Surv., 1883-84, p. 217.

become oxidised and hydrated, the carbonates removed in solution, and the aluminous minerals reduced to a soft yellow, buff-coloured or red clay at the outcrop.

Varieties due to differences of mineral composition.

37. All the rocks originally contained olivine in large quantities, but variations occur especially in the proportions of the augite and amphibole, and to a smaller extent, of the apatite. These ultra-basic rocks differ only slightly from the mica-olivine dolerites, which in the same way break through the coal-measures of the Barakar area, but which I have not found in the Giridih coal-field.[1]

The following are the principal types of ultra-basic rocks represented, with the primary minerals given in approximate order of quantity, the most abundant first:—

(1) Olivine-mica-apatite rock, with magnetite and chromite (9·876).
(2) Olivine-apatite-mica-augite-anthophyllite rock, with small quantities of spinellids (9·105).
(3) Olivine-mica-apatite-anthophyllite-augite rock, with spinellids (9·104).
(4) Olivine-mica-anthophyllite-augite rock, with apatite (9·707).
(5) Mica-olivine-anthophyllite-augite rock, with apatite (8·723).

Varieties due to differences of structure.

38. The rocks vary from a fine-grained variety with a matrix probably originally glassy to varieties composed of crystals measuring 2 or 3 mm. across with porphyritic crystals of olivine quite 10 mm. in diameter. In the former type phenocrysts of olivine occur in a pilotaxitic matrix; but biotite, which is so prominent in other types, occurs in rare and small crystals; being one of the latest minerals formed, this is only what might be expected. The olivines are generally replaced by rhombohedral carbonates with smaller quantities of a yellowish brown limonitic product, evidently a further stage in the decomposition of the ferro-magnesian silicates. The apatite crystals are still preserved, and by their arrangement in directions approximately parallel to the junction with the sandstone, show the direction of pressure to which the rock was subjected before final consolidation (9·109, fig. 3). Rocks of this structure would be included under those referred to by Professor Cole as ***compact peridotites***[2], and are equivalent to the ***picrite-porphyrites*** of Rosenbusch and the ***kimberlite*** of Carvill Lewis.

The holocrystalline types are granitic in structure and require no further notice under this head.

V.—SUMMARY.

39. The so-called "mica-traps" intrusive into the coal-measures, sandstones, and shales of Lower Gondwana age in Bengal, prove to be basic and highly phosphatic ultra-basic rocks (paras. 26, 27, 37).

"Mica-traps."

[1] The rock which for the present I have referred to as a mica-olivine-dolerite, is distinguished from the ultra-basic rocks by containing considerable quantities of felspar with a very small proportion of apatite; its magnetite also occurs in long laths instead of in granules. On account of these peculiarities, I have provisionally separated certain compact and partly decomposed specimens from the ultra-basic group until by fresher specimens their characters can be traced out more fully. Specimens so separated occur so far only in the Barakar-Rániganj coal-field.

[2] Aids in Pract. Geol. (1891), p. 220.

40. Members of the latter group invariably contain large quantities of *olivine* and *biotite* with *apatite*, which is always abundant and sometimes forms as much as 11 per cent. of the rock. Amongst the other primary minerals, *augite* and pleochroic *anthophyllite* take a prominent place, whilst *ilmenite*, *magnetite*, and *chromite* are variable. Amongst the secondary minerals *serpentine* and *magnetite* are the earliest products of alteration. These are followed by *perofskite* and *rhombohedral carbonates* which always contain magnesia. The final result of weathering is a ferruginous, yellow, buff-coloured or red *clay* (paras. 28—36).

Mineral composition.

41. In structure the rocks vary from the coarse holocrystalline varieties which form the central portions of the large masses, to compact peridotite forming the selvages of dykes and the smaller veins. In the latter the phenocrysts of olivine, apatite, and magnetite occur in a pilotaxitic matrix which probably originally contained some glass (paras. 16, 28, 38).

Structure.

42. The rock occurs as narrow dykes and intrusive sheets in the coal-fields of Dárjíling, Ránígani, Baríkar, Jherria, Deoghur, Girídíh and probably Rámgarh, thus occurring in places more than 250 miles distant from one another (paras. 10—13).

Occurrence.

43. As these dykes are younger than the Ráníganj series and older than the Rajmahál traps we have a petrographical province of about Pánchet age (para. 14).

Geological age.

44. As far as can be judged from descriptions, there is an interesting analogy between these rocks and those intruding into the Kimberley shales of South Africa, where, in carbonaceous beds of about the same age as the Damudas, a diamond-bearing peridotite is also associated with basaltic dykes, which are the underground representatives of the sub-aërial lava-flows capping the Stormberg beds, thus occupying a position corresponding to the Rajmahál traps of Bengal (para. 1).

Analogies with South African peridotites.

VI.—EXPLANATION OF PLATE I.

Fig. 1. Olivine-biotite-apatite rock with magnetite and chromite. Central portion of a large mass in No. 7 Jogitand shaft, Giridih coal-field (9·876).

Fig. 2. Olivine-biotite-apatite-augite-anthophyllite rock with iron-ores and a decomposed grey groundmass. The olivines in this rock are almost completely serpentinised (9·105). From another dyke in the same shaft.

Fig. 3. Compact peridotite showing fluidal structure by pressure at the selvage of a dyke intruding into sandstone. Apatite crystals occur as numerous rods; olivines mostly replaced by carbonates and limonite; magnetite scattered through the pilotaxitic groundmass. Sibpore Colliery, Assensole (9·109) (see p. 140).

Fig. 4. Crystal of olivine showing two series of cracks (9,876) (see p. 137).

Fig. 5. Microlites developed by maintaining the artificially-produced glass of No. 9·105 at a bright red heat for 12 hours (see p. 134). Sp. gr. 2·99.

All magnified $\times 45/2$.

On a Mica-Hypersthene-Hornblende-Peridotite *in Bengal*—By THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India.*

I.—INTRODUCTION.

Taking the essential and primary constituents in their approximate order of proportion, the peridotite from Mánbhúm described in this paper may be classed as an olivine-hornblende-biotite-hypersthene-augite rock with accessory pyrrhotite and pyrites.

A certain amount of interest attaches to a rock of this composition—

(1) On account of the very small number of peridotites known in which biotite is a primary and an essential constituent.

(2) On account of the still smaller number of mica-hornblende-peridotites known.

(3) On account of the presence also of hypersthene which, with primary olivine, biotite and hornblende, forms a combination of minerals it seems hitherto undescribed.

(4) On account of the proximity of this rock to the Bengal coal-fields in which mica-peridotites of a very peculiar character pierce the sedimentary rocks in all directions.[1]

(*i*) *Previously described Mica-Peridotites.*

An *olivine-biotite rock* with blue-green spinel, titaniferous iron, augite and plagioclase as accessories associated with the gabbro mass of the Harz, was described in 1889 by Max Koch[2]. This seems to have been the first mica-peridotite described.

In 1892 C. H. Smyth described a *mica-peridotite* occurring as a dyke of late carboniferous age in Central New York.[3] The structure of this rock in being distinctly hemi-crystalline like kimberlite, agrees strikingly with that of some of the varieties of mica-apatite-peridotites occurring as intrusions in the Bengal coal-fields.

Later in the same year J. S. Diller published an account of a *mica-peridotite* from Kentucky describing it as a dyke-rock composed essentially of biotite, serpentine and perofskite, with smaller proportions of apatite, muscovite, magnetite, chlorite, calcite and some other secondary products. In this rock also there are considerable quantities of a brownish grey clouded material without crystallographic outline or such physical features as definitely indicate its origin.[4] From the description it resembles the substance which in the mica-apatite-peridotites I have referred to decomposed and devitrified residuary matrix.

[1] The locality in which the rock was found is on the southern border of the Jherria coal-field and is only 36 miles west of Raniganj. The peridotites referred to are described in a separate note (*Rec., Geol. Surv., Ind.*, vol. XXVII (1894), p. 129).

[2] *Zeitschr. d. Deutsch. geol. Ges.*, vol. XLI (1889), p. 163.

[3] *Amer. Journ. Sci*, 3rd ser., vol. XLIII (1892), p. 322.

[4] *Amer. Journ. Sci.*, 3rd ser., vol XLIV (1892), p. 286.

(2) *Previously-described Mica-Hornblende-Peridotites.*

The well-known *Schillerfels* of Schriesheim in Baden described by Cohen is a hornblende-peridotite (hudsonite, cortlandtite) with mica, which apparently is less prominent than in the Mánbhúm peridotite.[1]

The nearest ally to the Mánbhúm specimens seems to be the rock described as *scyelite* (mica-hornblende-picrite) from Caithness by Professor Judd. In this rock, however, the pyroxenes which once existed have been completely changed to amphibole.[2]

Amongst the peridotites of the Cortlandt series near Peekskill, New York, the late Prof. G. H. Williams described as hornblende-peridotite (*cortlandtite*) a type in which, besides the essential constituents hornblende and olivine, there occur hypersthene, augite, biotite, felspar, spinellids and pyrrhotite in subordinate quantities.[3] This rock, therefore, very nearly approaches the Mánbhúm peridotite, but the biotite again appears to be far less prominent.

In 1892 Messrs. Dakyns and Teall described an *enstatite-diallage-hornblende-biotite-olivine rock* from amongst the plutonic intrusions near the head of Loch Lomond in Scotland.[4] In this rock the small quantity of both biotite and olivine remove it from the Mánbhúm type.

The rock described in 1880 by Sir Archibald Geikie as a *picrite* from the Island of Inchcolm, Firth of Forth, contains olivine and its serpentinous products, augite, biotite, plagioclase and its secondary products, and iron-ores with, according to Mr. Teall, hornblende and apatite. The hornblende, however, is variable and sometimes absent, whilst the biotite occurs only as occasional long scales and according to Mr. Teall is possibly of secondary origin.[5]

Other described peridotites contain subordinate quantities of brown mica, for example, Pen-y-Carnisiog Anglesey (Bonney),[6] Gipp's Land (Bonney),[7] Pike county, Arkansas (Branner and Brackett)[8], Elliott county, Kentucky (Diller)[9] Taberg, Sweden (Törnebohm),[10] but in these cases there is an absence of the pyroxene, or hornblende, or both. I know of no case, therefore, similar to that of the Mánbhúm peridotite.

II.—MODE OF OCCURRENCE.

Specimens of this rock, labelled "hornblende rock" (No. 3·22), were collected by the late Mr. Fedden in the season 1865-66 near the Ijri river, west of Bhurro (Lat. 23° 37′ N., Long. 86° 30′ E.) in the Mánbhúm district. It is associated with the other crystalline rocks near Chypabad and Palkuree, and according to Mr. Fedden

[1] *Neues Jahrb. fur Min.*, 1885, vol. I, p. 242.
[2] *Quart. Journ. Geol. Soc.*, vol. XLI (1885), p. 401, plate XIII, fig. 8
[3] *Amer. Journ. Sci.*, 3rd ser., vol. XXXI (1886), p. 29.
[4] *Quart. Journ. Geol. Soc.*, vol. XLVIII (1892), p 112.
[5] Geikie, *Trans. Roy. Soc. Ed.*, vol. XXIX (1880), pp. 506–508. Teall, Brit. Petrography, 1888, pp. 94—96, and plate IV, fig. 2.
[6] *Quart. Journ. Geol. Soc.*, vol. XXXVII (1881), p. 138.
[7] *Min. Mag.*, vol. VI (1884), p. 54.
[8] *Amer. Journ. Sci.*, 3rd ser., vol. XXXVIII (1889), p. 50.
[9] *Ibid.*, 3rd ser., vol. XXXII, (1886), p. 121, and *Bull. U. S. Geol. Surv.*, No. 38, 1887.
[10] *Neues Jahrb. Min.* (1882), vol. II, p. 66.

can be traced westward through Futtoodee to Bagoolah, where it forms a large mass. Between Hotoopathar and Partand, 6 miles west-north-west, it is exposed in a mass running north-west and cropping out at right angles to the mica-schists and gneisses.[1]

III.—PETROLOGICAL CHARACTERS.

The specimens exhibit in a striking manner the lustre-mottling which is so characteristic of hornblende peridotites; and in this case the structure is due to the bright cleavage-faces of the hornblendes and the ophitically disposed scales of biotite, which often determine the fracture of the rock. The specific gravity is 3·231.

Under the microscope the following minerals are distinguished:—

- Apatite.
- Olivine.
- Pyroxene (Hypersthene and Augite).
- Biotite.
- Hornblende.
- Magnetite.
- Pyrite and Pyrrhotite.
- Felspar.

Apatite occurs in sparsely distributed crystals measuring up to 0·25 mm. in diameter. Rod-shaped cavities are arranged parallel to the vertical axis.

Olivine, colourless and without crystalline form, is included by all the other minerals. A striking feature in this mineral is the separation of magnetite in stellar and dendritic markings reaching sometimes 0·1 mm. long, like those described by Professor Judd in the olivines of a picrite from Halival, Isle of Rum.[2] In the olivines of this rock also the branches of the dendrites frequently exhibit rectilinear limits as if bounded by the edges of negative crystals in the olivines, and these straight lines are always parallel to a direction of extinction; they are parallel, therefore, to one of the crystallographic axes. In sections cut at right angles to these inclusions they appear as lines and rows of dots: on examining these sections with a quartz wedge there is an appearance of thinning when the axis of the wedge is placed parallel to the inclusions; the inclusions therefore cannot lie in the brachypinacoid.[3] As only one set of inclusions is present they are presumably not parallel to the prism faces; they are, therefore, either parallel to the macropinacoid or the basal plane. Several sections approximately parallel to the inclusions have been made, and these invariably give at least a partial interference figure; as the optic axial plane is parallel to the basal plane in olivines, it may be concluded that the sections parallel to the inclusions are macropinacoidal.[4] Irregular cracks traverse the olivines in all directions and sometimes cross the

[1] Fedden, MS. report on parts of Mánbhúm and Hazaribágh, 1865-66.

[2] *Quart. Journ. Geol. Soc.*, vol. XLI (1885), p. 381, and plate XII, figs. 2-7.

[3] In olivine with positive double refraction (as shown by this mineral) $\mathfrak{a}=b$, $\mathfrak{b}=c$ and $\mathfrak{c}=a$.

[4] No crystallographic faces or trustworthy cleavage cracks being exhibited, this statement has to be made without the confirmation desirable. Tabular inclusions parallel to the macropinacoid are curiously like the shapes of fayalite crystals.

dendritic plates. These cracks are also filled with black material which is often arranged in a dendritic fashion; but these lie in irregular positions, and the dendritic growths are analogous to those of the well-known manganese-oxide infiltrations in the joint-planes of rocks. There are other cavities irregular in shape and often joined to one another by tortuous canals; these are generally partially filled with black stones.

The olivines in this rock show scarcely a trace of serpentinisation, and in this respect present a striking contrast to those of the mica-peridotites in the adjacent coal-fields. It is noteworthy also that in the latter rocks the dendritic products of schillerization are quite wanting.

Pyroxenes.—When free of inclusions the *hypersthene* shows a distinct pleochroism in thin sections (pale pink to almost colourless). The majority of the crystals are schillerised, the plates lying, as in that from St. Paul, parallel to a direction of extinction. The colours between crossed Nicols are low. Polarisation-effects of a distinctly higher order are exhibited by a colourless mineral occurring in granular aggregates and less often as isolated crystals. In these crystals the rod-like inclusions crossing one another nearly at right angles are so numerous that a satisfactory determination of the optical properties of the mineral could not be made. All extinctions from the directions of the inclusions, as well as from the cracks occasionally presented, are oblique, and as the mineral is unaffected by hydrochloric acid, it has been taken for *colourless augite*, which would not be remarkable in this association. The crystals, too, are patched all over with green hornblende which has apparently developed by paramorphism.

Hornblende occurs in two forms—a brown variety in crystals 40 mm. or more in length and including all the other minerals in the rock except biotite, and a green variety of later development, being the result of the paramorphism of augite and occurring in isolated patches with the granular aggregates of this latter mineral, as well as on the margins of, and in optical continuity with, the larger brown hornblendes. The extinction-angle of the large crystals is noticeably wide, the maximum measurement being 22°. The quartz-wedge placed along the direction of extinction in clinopinacoidal sections gives (with crossed Nicols arranged at 45° to the quartz-wedge) an appearance of thickening. Taking this direction as the axis of optical elasticity $\mathfrak{c}$ we have the pleochroism:—

$\mathfrak{c}$ = deep brown.

$\mathfrak{a}$ = very pale brown with a tinge of green;

and from cross-sections showing the characteristic prismatic cleavage,

$\mathfrak{b}$ = deep greenish brown.

Sections, therefore, parallel to $\mathfrak{b}$ and $\mathfrak{a}$ are not strikingly pleochroic. Minute rod-like inclusions arranged parallel to the cleavage-cracks appear sparsely distributed through the longitudinal sections. The green hornblende calls for no special remark.

Biotite, by its cleavage, often determines the direction of fracture in the rock. It is intergrown with hornblende, and apparently is of later development than any of the other primary constituents. Basal plates show a very narrow optic-axial angle, and in the same sections numbers of brown and black plates, sometimes hexagonal in shape, are arranged parallel to the cleavage-plates. I have not been able to discover that these have any definite crystallographic disposal

of their edges with reference to the percussion-figure. Associated with the plates are fine hairs which are often arranged at angles of 60° to one another. These are generally referred to sagenitic rutile, but a careful chemical examination of a number of flakes gave no reactions for titanium. Whether a portion or the whole of these inclusions are primary or secondary cannot be decided by this specimen alone, but the fact that distinct schillerization with definite crystallographic disposal of the secondary products is exhibited by the other minerals in the rock, points to a similar origin for the blemishes in the biotite.

Iron-ores.—The *magnetite* is almost wholly secondary, the olivines being sometimes almost opaque from the separation of this mineral. Granules of *pyrrhotite* and *pyrite* measuring up to 5 mm. in diameter are sparsely scattered through the rock. A test for metallic iron gave negative results.

Plagioclase occurs in very small quantity apparently infilling cavities as if of secondary origin. The crystals are clear, unschillerized and generally twinned. Simultaneous extinction occurs in patches separated by distances of 2 mm. or more. The extinction-angles agree with those of labradorite.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

No. 21.—ENDING 31ST OCTOBER 1894.

Director's Office, Calcutta, 31st October 1894.

The programme for the next field season (1894-95) has been arranged as follows:—

SCIENTIFIC.

Central India.—Mr. R. D. Oldham, Superintendent.

Mr. P. N. Datta, Assistant Superintendent, and an Assistant Superintendent about to be appointed by the Secretary of State.

Central Provinces.—Mr. P. N. Bose, Superintendent.

Madras.—Mr. C. S. Middlemiss, Deputy Superintendent.

Burma.—Dr. Fritz Noetling, Palæontologist.

Baluchistan.—Mr. F. H. Smith, Assistant Superintendent.

ECONOMIC.

Sukkur Experimental Boring, and Economic Geology of Baluchistan :—
Mr. T. D. La Touche, Superintendent.
Lala Hira Lal.

Madras and Burma.—Dr. H. Warth.

Chota Nagpore.—A specialist about to be appointed by the Secretary of State.

The Director and Mr. Holland will be at Headquarters during the coming season.

Mr. Hughes, Superintendent, is still on sick leave; Mr. Oldham re-joined his appointment on the 17th instant from furlough, during which he had occasion to visit the Galician oilfields with permission of the Secretary of State. Lala Kishen Singh is on furlough and Lala Hira Lal on privilege leave, which he re-joined on the 16th instant.

During the last three months most of the officers have been in recess-quarters for the purpose of working up their maps and notes, and all have sent in their progress reports for the last field-season.

Important work has been done and is still in progress in the Laboratory under Mr. Holland, who is ably assisted by Mr. Blyth, the Museum Assistant. The re-arrangement and cataloguing of the mineral and rock collection is a work of paramount importance, and it is hoped will be completed during the coming cold weather.

Dr. Noetling was engaged for several months past in working out and describing some important collections of fossils. The tertiary fossils of the Yenangyoung oil-tract have been described and figured and will shortly appear as part 1 of Vol. XXVI of the Memoirs. A still more important suite of fossils, namely those collected by the survey in Baluchistan, has been subjected to critical examination, and the first instalment of a new "series" of the Palæontologia Indica will be published as soon as the plates belonging to it are lithographed in the office. It will contain the jurassic fossils of Baluchistan.

The overflow of the Gohna Lake.—It will be remembered that a landslip occurred early in September 1893 and dammed up the Birahi Ganga which drained 90 square miles above Gohna. The locality was examined by Mr. Holland early in March 894, when the lake was nearly 3 miles long with a maximum width of 1 mile. Mr. Holland's report described (1) the geographical and geological features of the Birahi Ganga valley, (2) a description of the landslip and lake, and (3) a discussion of the causes which led to the landslip.

With regard to the second point he predicted :—

(1) That the lake would be full and would overflow the barrier about the middle of August.

(2) That the dam was strong enough to resist the pressure of the water before overflow.

(3) That after overflow the lake would be reduced to one about 3¼ miles long, and that this would remain permanent for some time.

(4) That landslips would occur into the lake.

The lake overflowed the dam early on the morning of August 25th, the stream flowing down the steep slope to the bed below Gohna. The erosion thus continued until late at night when a channel having been cut back to the lip of the lake a rapid recession of levels followed until the erosion was checked by reduction of the slope and exposure of large blocks of dolomite, by removal of the fine detritus forming the upper part of the dam. The lake left is about 3 miles long and over 300 feet deep, with, according to the latest accounts, every chance of being historically permanent, although its gradual destruction by silting up of the basin and gradual erosion of the dam will, geologically considered, happen at no distant time. The landslips which have occurred into the lake have with the silt raised the bottom nearly 100 feet. The dam is now quite firm and the outlet through the gorge cut in its upper part is over a rocky bed with a slope of about 1 in 15.

In this gorge, cut through a portion of the first of the two main falls, there are exposed, according to Lieutenant Crookshank, R.E., great bundles of strata dipping towards the south at an angle of about 50°, which he regards as a striking confirmation of Mr. Holland's conclusion with regard to the peculiar character of the first slip in which Mr. Holland considered that the hill must have pitched forward and not have slipped down in stream fashion after the manner of smaller and more common landslips. (Records, vol. XXVII, page 59.)

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894.

Substance.	For whom.	Result.
1 Specimen of quartz, with iron pyrites, from Dongreea hill, Bhandara Dist., C. P., for Gold.	P. N. DATTA, Geological Survey of India.	Contains no Gold.
3 Specimens of manganese ore (*Braunite* with *psilomelane*), from the Central Provinces.	P. N. DATTA, Geological Survey of India.	o/1008 1 mile N. of Seetasaongee, S. by W. of Chicklah. *Quantity received* 3½ oz. 61·08 9/1002 ½ mile N. by E. of Koodmoora village *Quantity received* ½ lbs. 35·97

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894—continued.

Substance.	For whom.	Result.
		$\frac{9}{998}$ Dhola hill, S. of Beemasoor Peak, Chicklah. *Quantity received* $1\frac{3}{4}$ oz. Percentage o man-ganese (Mn.) . . . . 43'97
1 specimen from near Goona, Gwalior, for examination.	Col. D. G. Pitcher, Director of Land Records, Gwalior State.	Fibrous Calcite.
Rocks from the Sone Valley, Rewah State	P. N. Bose, Geological Survey of India.	$\frac{9}{1050}$ Slide 1299. From the Sone, Rampurwa, Ramnagar Tahsil. BIOTITE-GNEISS WITH LEPTYNITE VEINS—The hand-specimen shows black-mica gneiss with bands of leptynite arranged parallel to the direction of foliation. Under the microscope the structure is granulitic to granitic. The minerals are:—*Quartz* in bands of granules with liquid-bearing cavities in rows. *Felspar,* sometimes showing lamellar twinning. The central portions of the crystals are grey or brown by the abundance of kaolinized products. The margins are clear and appear sometimes to be of secondary growth. *Biotite* in irregular highly pleochroic bundles α = greenish-yellow; β and γ = dark-green with almost complete absorption. Seldom fringed with chlorite. *Colourless mica* occurs in very small quantity. *Apatite* in sparse stumpy crystals. *Iron-ores* occur very rarely. *Epidote* is developed in large quantities. $\frac{9}{1051}$, Slide 1300. From the Sone at Rampurwa, Ramnagar Tashil.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894—continued.

Substance.	For whom.	Result.
		APHANITE— Occurs in contact with gneissose granite. The section under the microscope appears like a net-work of finely, granular green *hornblende* enclosing almost colourless *augite*, *plagioclase felspar* and possibly *quartz*. Granular *iron-ores* appear to be a product of the change of the augite. $\frac{8}{1089}$, Slide 1301. Sukha river, north of Sidi, Sahaol Tahsil. APHANITE— Occurs penetrating granite. The rock is composed almost entirely of actinolitic *hornblende* and decomposed *felspar*, with mesh-like patches of *iron-ores*. By parallel arrangement of the fibres the actinolite sometimes shows simultaneous extinction over considerable areas. Originally the rock was probably an augite-plagioclase rock. $\frac{8}{1088}$, Slide 1302. Marka, Sahaol Tahsil. QUARTZ-APHANITE, intrusive in the transitions. Differs from the last only in the introduction of *quartz* and in the numerous needles of *apatite*. $\frac{8}{1084}$, Slide 1303. Deora, Sahaol Tahsil. Decomposed amygdaloidal ANDESITE, interbedded in the Bijawars. The cavities arranged in parallel bands have been infilled with *calcite* and *chlorite*. Under the microscope, there is a ground-mass of felted microlites of two minerals, which, from their different double refractions, appear to be *hornblende* and *felspar*. Opaque white patches scattered through the ground-mass could not be determined. Well-shaped and sometimes twinned crystals of *epidote* form the most striking feature in the sections. $\frac{8}{4}$, Slide 1306. BIOTITE-GNEISS WITH LEPTYNITE VEINS like No, $\frac{8}{1087}$, slide 1299, from the Sone, Rampurwa, Rewah State. $\frac{8}{7}$, Slide 1305. AMPHIBOLITE— Satnara, south-east of Sidi, Sahaol Tahsil. Dark-green tough rock with bright phenocrysts of *hornblende* measuring up to 5 mm. long. Ragged masses of magnetite in fair quantity are made out under the microscope, but the large crystals of hornblende make up the principal mass

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of August, September, and October 1894– concluded.

Substance.	For whom.	Result.
		of the rock. These are imbedded in a fine-grained matrix of green hornblende and microcrystalline aggregate of *quarts* and *felspar* in small quantities. $\frac{19}{80}$, Slide 1307. MICA-SYENITE. Harbora, Sahaol Tahsil. Pink *felspar* and small quantities of *quarts* with dark-green *hornblende* and *chlorite* are easily seen with the naked eye. Under the microscope the following minerals are distinguished :— *Apatite*, dark-green *hornblende*, *biotite* almost completely changed to *chlorite*, *felspar* principally orthoclase, sometimes plagioclase always kaolinised, and *quarts* in small quantities showing a feeble attempt at micrographic intergrowth with the felspar. $\frac{18}{113}$, Slide 1304. EURITE (devitrified rhyolite approaching syenite-felsite). Ponri, east of Kua, Ramnagar Tahsil. The hand specimen is compact, has a conchoidal fracture and grey colour like many eurites. Phenocrysts of *felspar* are more common than those of *quarts* which occur in small granules. Some of the felspar is plagioclase. The matrix is microcrystalline and shows fluidal structure.

Notifications issued by the Geological Survey of India during the months of August, September, and October 1894, published in the "Gazette of India," *Part II.—Leave.*

Department.	No. of order and date.	Name of officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Geological Survey Department.	2047, dated 21st September 1894.	Dr. H. Warth, Deputy Superintendent, Geological Survey of India.	Privilege.	23rd September 1894.	...	...

Annual increments to graded officers sanctioned by the Government of India during August, September, and October 1894.

Name of officer.	From	To	With effect from	No. and date of sanction.	REMARKS.
	R	R			
F. H. Smith, Assistant Superintendent, Geological Survey of India.	410	440	1st August 1894.	Revenue and Agricultural Department No. $\frac{2484}{185}$, Surveys, dated 30th August 1894.	
T. H. D. LaTouche, Superintendent, Geological Survey of India.	800	850	1st April 1893.	Do. No. $\frac{2677}{187}$, Surveys, dated 4th October 1894.	
Ditto	850	900	1st April 1894.	Ditto	
P. N. Bose, Officiating Superintendent, Geological Survey of India.	950	1,000	Do	Do. No. $\frac{2679}{188}$, Surveys, dated 4th October 1894.	

Notifications issued by the Government of India during the months of August, September, and October 1894, published in the "Gazette of India," *Part I.—Appointment, Confirmation, Promotion, Reversion and Retirement.*

Department.	No. of order and date.	Name of officer.	From	To	Nature of appointment, etc.	With effect from	REMARKS.
Revenue and Agricultural Department.	$\frac{3101}{14}$, Surveys, dated 21st August 1894.	T. H. D. La Touche.	Officiating Superintendent, Geological Survey of India.	Superintendent, Geological Survey of India.	Substantive, permanent.	17th July 1894.	...
Ditto .	Do. .	T. H. Holland.	Assistant Superintendent, Geological Survey of India.	Deputy Superintendent, Geological Survey of India.	Ditto .	Ditto .	...
Ditto .	$\frac{2950}{14}$, Surveys, dated 11th October 1894.	P. N. Bose.	Deputy Superintendent, Geological Survey of India.	Superintendent, Geological Survey of India.	Officiating.	Ditto .	...
Ditto .	Do. .	C. S. Middlemiss.	Ditto .	Ditto .	Ditto .	Ditto .	...
Ditto .	Do. .	P. N. Datta.	Assistant Superintendent, Geological Survey of India.	Deputy Superintendent, Geological Survey of India.	Ditto .	Ditto .	...

Postal and Telegraphic addresses of Officers.

Name of Officer.	Postal address.	Nearest Telegraph Office.
T. W. H. HUGHES	On furlough	..
R. D. OLDHAM	Rewa	Rewa.
T. H. D. LATOUCHE	Sukkur	Sukkur.
P. N. BOSE	Raipur	Raipur.
C. S MIDDLEMISS	Ootacamund	Ootacamund.
H. WARTH	On privilege leave	...
T. H. HOLLAND	Calcutta	Calcutta.
P. N. DATTA	Rewa	Rewa.
W. B. D. EDWARDS	On furlough	...
F. H. SMITH	Quetta	Quetta.
F. NOETLING	Calcutta	Calcutta.
HIRA LAL	Sukkur	Sukkur.
KISHEN SINGH	On furlough	...

DONATIONS TO THE MUSEUM.

FROM 1ST AUGUST TO 31ST OCTOBER 1894.

A core of Barakar sandstone from Giridih (Karharbari) coal-field, 300 feet below surface of ground, and 600 feet above lower coal seam.

PRESENTED BY DR. W. SAISE, A.R.S.M., F.G S.,
Manager, E. I. Ry. Collieries.

Specimens of the crystalline rocks in the neighbourhood of the Giridih coal-field.

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Manager, E. I. Ry. Collieries.

Specimens of mica-peridotites and dolerites from dykes in the neighbourhood of Asansol.

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Manager, E. I. Ry. Collieries.

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Specimens of coal altered by intrusions of peridotite, Cheranpore, Asansol.

PRESENTED BY F. J. AGABEG.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1894.

Titles of Books. *Donors.*

BECK, *Dr. Ludwig.*—Die Geschichte des Eisens. Abth. II, lief. 2—5. 8° Braunschweig, 1893.

BEHRENS, *Prof. H.*—A manual of micro-chemical analysis. 8° London, 1894.

BRONN, *Dr. G. H.*—Klassen und ordnungen des Thier-Reichs. Band III, lief. 2-3, and 10—14. 8°. Leipzig, 1894.

BRÜHL, *Carl Bernhard.*—Das Skelet der Krokodiliner. 4° Wien, 1862.

COOLEY'S Cyclopœdia of practical receipts. 7th Edition. Edited by W. North. Vols. I—II. 8° London, 1892.

COTTEAU, *G.*—Echinides Nouveaux ou peu connus. Series I, Nos. 1—16, and II, Nos. 1—12. 8° Paris, 1858—1878.

DAUBRÉE, *A.*—Les Regions Invisibles der Globe et des Espaces Celestes. Deuxiéme Edition, Vol. LXII. 8° Paris, 1892.

DAVIES, *E. H.*—Machinery for Metalliferous Mines. 8° London, 1894.

FOSTER, *C. Le Neve.*—A Text-Book of Ore and Stone Mining. 8° London, 1894.

HULL, *E.*—Book on Mount Seir, Sinai and Western Palestine. 8° London, 1889.

" Memoir on the Geology and Geography of Western Palestine. 8° London, 1889.

" Volcanoes: past and present. 8° London, 1892.

JOHNSTON, *Prof.*—Elements of Agricultural Chemistry and Geology. 8° London, 1894.

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LARTET, LOUIS.—Exploration Géologique de la Mer Morte. 4° Paris, 1877.

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LEVY, *A. Michel.*—Structures et classification des Roches Eruptives. 8° Paris, 1889.

LIVERSIDGE, *A.*—Origin of Moss Gold. 8° Pam., London, 1893. THE AUTHOR.

LOUIS, *Henry.*—Handbook of Gold-milling, with illustrations. 8° London, 1894.

MALLARD, *M. E.*—Traite de Cristallographie Geometrique et Physique. Tome I-II, and Atlas. 8° Paris, 1879.

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ERRATUM.

RECORDS, GEOLOGICAL SURVEY OF INDIA, VOL. XXVII, PART 4.

Map facing page 115, the scale should be 1″=4 miles instead of 1″=16 miles.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1895. **[February.**

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1894.

Staff of the Survey.

Dr. William King retired from the Directorship on the 16th July last, after a total length of service of 37 years, seven of which were passed as Director. His services are briefly noticed in the Records, Vol. XXVII, page. 109.

Mr. T. W. H. Hughes was compelled to retire from the 17th October, owing to an unfortunate accident, which has deprived him of his eyesight.

Mr. W. B. D. Edwards, having obtained an appointment as Inspector of Schools in England, has resigned his appointment from the 4th November 1894.

The vacancies thus created will be filled in due course by men selected by Her Majesty's Secretary of State.

Mr. William Anderson was appointed by the Secretary of State to be Mining Specialist on the Survey, and joined the Department on the 15th November 1894.

At the beginning of the year 1894, the officers of the department not on leave were disposed as follows :—

Myself with Mr. F. H. Smith and Lala Kishen Singh in Baluchistán; Mr. T. H. D. La Touche in charge of boring at Sukkur; Mr. P. N. Bose, Rewah; Mr. C. S. Middlemiss, Madras; Dr. H. Warth, Madras; Mr. P. N. Datta, Central Provinces; Mr. T. H. Holland and Dr. F. Noetling at Head-Quarters.

At the beginning of the present field-season the officers of the department were distributed as follows :—

Mr. R. D. Oldham and „ Datta	Rewah.
Mr. LaTouche and Lala Hira Lal	Sukkur.
Mr. P. N. Bose	Central Provinces.
„ Middlemiss	Madras.
„ Holland	Head-Quarters.
„ Smith	Baluchistán.
Dr. Noetling	Upper Burma.
Mr. Anderson	Chota Nagpore.

Summary of work accomplished.

In the following notes will be found an outline of the work done during 1894.

Rewah.
P. N. Bose.
R. D. Oldham.
P. N. Datta.

During the season of 1893 to 1894 Mr. Bose surveyed a rather extensive area in Rewah and the ground east of it, in all more than 2,000 square miles, of which, however, some parts had already been reported on by Mr. Smith and Kishen Singh, who were attached to the party under Mr. Hughes in 1893. Mr. Bose distinguishes the following formations in descending order:—

4. Gondwanas.
3. Vindhyans.
2. Transitions.
1. Metamorphics.

and amongst the intrusive rocks: granite and diorite.

He separates a schistose formation from the transitions proper, *i. e.* the representatives of the Bijáwar system, and includes a belt of gneissose rocks amongst the former, being probably the result of local metamorphism of the schistose series by the intrusive granites. The lower vindhyans rest unconformably on the transitions.

Mr. Oldham has taken over charge of the Rewah survey this field-season, with Mr. Datta to assist him; he has since had an opportunity of inspecting Mr. Bose's work, and has come to the conclusion that the so called "gneiss" of Mr. Bose is in reality an intrusive granite. Mr. Oldham has not yet been able to confirm the separation of the schistose beds from the transitions. If the "gneiss" is only intrusive granite, it seems very probable that the difference in lithological character between the schistose and transition series is due to contact metamorphism. Mr. Bose describes the two series of rocks as conformable and renders their position in this manner in his section.

I myself crossed this belt of transition rocks further eastwards some years ago and was struck at that time with the general resemblance of the series with the great thickness of beds which underlie the lower silurian of the Himálayas, which I had comprised under the name of the haimantas and of which the upper portion may possibly be correlated with the cambrians. I still believe that this series of transitions underlying the lower vindhyans will turn out to be an equivalent of the haimanta group of the Himálayas.

Mr. Datta is working at the lower vindhyans north of the Sone and has been able to examine some sections in greater detail, but so far Mr. Oldham suspects that the lower vindhyans (so-called) belong to a different and unconformable series to the vindhyans proper in which opinion he differs from Mr. Mallet. (See Vol. VII of the Memoirs.)

Central Provinces.
P. N. Datta, 1893-94.
P. N. Bose, 1894.

Mr. Datta had been posted to the Bhandara District during the previous field-season, and he was engaged at the beginning of 1894 on the geological survey of part of a still unknown ground in the Central Provinces. He managed to go over two separate areas, namely, part of the valley of the Kanhun river in Nagpur and Chindwara, and secondly, parts of the Bhandara district. In the first-named district he came across a crystalline and schistose series with intrusions and spreads of igneous rock, which is unconformably overlaid by lameta beds; the latter proved unfossiliferous.

In the second or Bhandara area Mr. Datta observed crystalline rocks with

transition beds, the series forming the western extension of the Chattisgarh basin. A number of sections were examined in detail, but until the rock-specimens can be examined microscopically, not many new facts can be made out regarding the structure of that part of India. Mr. Datta has brought back a fine collection of hand-specimens for the museum.

At the beginning of last field-season Mr. Bose was posted to the same ground, and he started work in continuation of the surveys of Dr. King in the Chattisgarh division. He believes to have met with confirmatory evidence in favour of the unconformable superposition of certain beds over the Chilpi Ghât series, which may possibly represent lower vindhyans in this area. It is a point, however, which will require much clearer evidence before this view can be finally adopted. It is directly opposed to both Mr. Medlicott's and Dr. King's views (for the latter see Records, Vol. XVIII, p. 190).

Madras.
Mr. C. S. Middlemiss.
Dr. H. Warth.

During December 1893, Mr. Middlemiss was transferred to the Madras Presidency, where he began a detailed investigation of the mineral resources and petrology of the Salem district, with special reference to the occurrence of corundum.

During the first few months of 1894, a cursory examination of the ground was only made, but nevertheless some very valuable observations were the result; he came to the conclusion that the corundum is not an original mineral constituent of the gneissose rocks in which it occurs, but is the result of a mineral change or metamorphism of the matrix rock. He infers this from the patchy way in which it occurs, from the zone, or shell of carbonate of lime and of quartz (at Sithampundi), and from the similar shell of pink felspar enclosing the corundum crystals in the Paparapatti rock. The general aspect is, as if it had segregated out in certain places, leaving an enclosing lenticular patch of altered gneiss and an envelope of another mineral behind. This field-season Mr. Middlemiss is provided with the necessary outfit for a microscopic examination of the rocks, and we may expect a large addition to a more exact knowledge of the petrology of Madras, which, it is to be hoped, will eventually form a useful and more or less complete guide to the crystalline rocks of India. He divides the Salem rocks provisionally as follows:—

Crystalline gneissic rocks—

(1) White and grey quartzo-felspathic rocks.
(2) Purple and grey biotite gneissic do.
(3) Hornblende gneissic do.
(4) Hypersthene gneissic do.

The above, though mutually interbanded in places, also predominate individually over certain areas. Hence they may be separated when traversing from East to West:—

(a) The Morappur	band of	hornblende	gneissic	rocks.
(b) The Mukhunur	"	hypersthene	"	"
(c) The Dharmapuri	"	quartzo-felspathic	"	"
(d) The Paparapatti	"	biotite with corundum.	"	"

Foliation of the above varieties seems to be genuine, consisting of (1) layers of different width, often contorted, composed of different minerals, and combinations of minerals, (2) layers of different degrees of coarseness of grain. The rocks are not as a rule fissile to any extent along the foliation.

Intrusive rocks—

(A). Purple granites are non-foliated massive rocks, occurring sparsely and are intruded along foliation of gneissic rocks. They often include large pieces of hornblendic rocks.

(B). Dark traps, doleritic, composition augite and plagioclase, non-foliated, tough, massive dyke rocks, crossing the foliation of the gneissic rocks at right angles; fairly numerous, but difficult to trace far, except locally.

The cretaceous rocks of Pondicherry; Dr. H. Warth.

It was desirable to study the cretaceous beds of Pondicherry in greater detail, and collect therefrom good material for description; Dr. Warth was deputed to do so, and he devoted the field-season of 1893-94 to this task.

The fossils which were collected by Dr. Warth are somewhat dissappointing, both as regards numbers and preservation, but they have been sent to Dr. Kossmat of the Vienna University, who is also engaged on the determination of the collection of cretaceous fossils from Trichinopoly belonging to the Madras Museum. From a preliminary note which this gentleman has sent it appears that the entire series of Pondicherry beds belongs to the Ariyalur group of Southern India.

Himálayas. Mr. T. H. Holland.

It will be remembered that a landslip occurred early in September 1893 and dammed up the Birahi Ganga which drained 90 square miles above Gohna. The locality was examined by Mr. Holland early in March 1894, when the lake was nearly 3 miles long with a maximum width of 1 mile. Mr. Holland's report described (1) the geographical and geological features of the Birahi Ganga valley, (2) a description of the landslip and lake, and (3) a discussion of the causes which led to the landslip.

With regard to the second point he predicted—

(1) That the lake would be full and would overflow the barrier about the middle of August.

(2) That the dam was strong enough to resist the pressure of the water before overflow.

(3) That after overflow the lake would be reduced to one about 3½ miles long, and that this would remain permanent for some time.

(4) That landslips would occur into the lake.

The lake overflowed the dam early on the morning of August 25th, the stream flowing down the steep slope to the bed below Gohna. The erosion thus continued until late at night, when a channel having been cut back to the lip of the lake rapid recession of levels followed until the erosion was checked by reduction of the slope and exposure of large blocks of dolomite, by removal of the fine detritus forming the upper part of the dam. The lake left is about 3 miles long and over 300 feet deep, with, according to the latest accounts, every chance of being historically permanent, although its gradual destruction by silting up of the basin and gradual erosion of the dam will, geologically considered, happen at no distant time. The landslips which have occurred into the lake have with the silt raised the bottom nearly 100 feet. The dam is now quite firm and the outlet through the gorge cut in its upper part is over a rocky bed with a slope of about 1 in 15.

In this gorge, cut through a portion of the first of the two main falls, there are exposed, according to Lieutenant Crookshank, R.E., great bundles of strata dipping towards the south at an angle of about 50°, which he regards as a striking confirmation of Mr. Holland's conclusion with regard to the peculiar character of the first

slip in which Mr. Holland considered that the hill must have pitched forward and not have slipped down in stream-fashion after the manner of smaller and more common landslips. (Records, Vol. XXVII, page 59.)

Punjáb.
Dr. F. Noetling.

The alarming increase of accidents in the Dandote coal-mines made an immediate inspection of the Dandote (Punjáb) and Warora (Central Provinces) collieries desirable; the Inspector of Mines in India had not been appointed then (October 1893), and Dr. Noetling was therefore deputed on this duty. In addition to this inspection, Dr. Noetling was able to add to our knowledge of the older palæozoic strata of the Salt-Range. He has since published his observations in a paper in the Records, Vol. XXVII, pages 71 to 86, which clears up many discrepancies in the Salt-Range geology.

Mr. Wynne, who described the geology of that range in greater detail, was the first observer who insisted on the age of certain beds as older than carboniferous and to be quite distinct from the latter. On the strength of Dr. Waagen's determination of the few fossils which had then been found, these beds were considered to be of silurian age. Later on Dr. Waagen combated this view and claimed a lower carboniferous age for these beds, but modified this opinion as cambrian trilobites were found, whilst his work, Vol. IV of Ser. XIII of the Palæontologia Indica, was in progress.

Dr. Noetling, who had studied the Khusak section carefully (already well described by Mr. Middlemiss, Records XXXIV, page 24) now divides the cambrian system of the Salt-Range as follows, in descending order:—

4. Bhaganwalla group, or salt-crystal pseudomorph zone.
3. Jutana group, or Magnesian sandstone.
2. Khussak group, or Neobolus beds.
1. Khewra group, or Purple sandstone.

Each of which divisions he further sub-divides.

The fossils which he has found, have been forwarded to Dr. Waagen for determination.

Sukkur boring.
Mr. T. D. La Touche.
Lala Hira Lal.

The boring for petroleum which has been put down at Sukkur on the Indus has steadily progressed, and it has been sunk to a depth of 957 feet. Considerable difficulty is occasionally experienced, but not more than might have been anticipated. The practical result is so far *nil*, although signs of escape of gas have been observed at depths below 800 feet, which afford some slight hope of obtaining oil further down. But the boring is not without some geological interest, as it proves that the thickness of the strata is much in accordance with the estimate which I have given, which was practically taken from the Sharigh section. The lithological character of the beds passed through is very similar to that of the Sharigh section, and in some respects, particularly in the upper portion, very like the section near Khattan. As near Sharigh, so also at Sukkur, a great thickness of clays, alternating with thin limestone bands, and traversed by numerous gypsum veins and nests, occurs below the light coloured upper nummulitic limestone of Sukkur.

The boring ought to reach the carbonaceous horizon within the next 200 to 250 feet, if the section corresponds as closely with the Sharigh section, as seems likely.

Mr. La Touche reported in December 1894 that he had examined a spot about 8 miles south of Rohri, where the freshly broken soil emits a strong smell of petroleum, which may indicate the escape of oil below the thickness of alluvium. There is no rock *in situ* within miles of the spot, but the question is being investigated now.

Baluchistán.
C. L. Griesbach.
W. B. D. Edwards.
F. H. Smith.
Lala Kishen Sing.

Considerable progress has been made in the geological survey of Baluchistán, which is, perhaps, one of the most interesting countries in the world, from a structural point of view.

Mr. Edwards joined my party in the early part of the year and was told off to examine the so-called Quetta coal-area. Before he could quite finish the task, he became seriously ill, which led eventually to his retirement this year.

Mr. Smith joined my party in the autumn of 1893, and after continuing the work which Mr. Edwards had begun, brought it to a close during this year.

He accompanied me afterwards (Spring 1894) on a tour to the Mari country, which I undertook to study certain sections which Mr. Oldham had reported on previously (Records, Vol. XXV, pages 18 to 29). Mr. Smith was instructed to take up work in continuation eastwards of Mr. Oldham's surveys, and he has since geologically mapped some 2,000 square miles of very interesting country east and south-east of the sections which are reported on in the paper quoted.

Mr. Smith has shown considerable acquaintance with field-work, and has prepared a number of working sections, drawn to scale. These, with the map, will be published later on, when the survey of that country has been completed.

During November and December 1894, Mr. Smith continued his former work in the high hills east and south-east of Quetta, which have now all been examined, with the result of confirming in most cases my first conjectures, which I expressed in Memoir, Vol. XVIII, part 1. When I visited that country in 1880 a close study of the sections was impossible, owing to the disturbed state the frontier was in at that time, but I concluded from the general structure of the country, that the Takatu hill mass represented a section comprising both cretaceous and lower eocene strata; Dr. W. T. Blanford in his Memoir, Vol. XX, part 2, combated this view, having had better opportunities of studying this particular section. My view, however, has now been amply upheld by Mr. Smith's subsequent work, and not only have upper cretaceous rocks (with belemnites) been found to constitute the main mass of the Takatu hills, but also evidence has been produced of the presence of older (neocomian and jurassic) limestones with fossils. The uppermost portion of the hill-mass is lower nummulitic as represented in my memoir. A fault separates this section from younger eocene beds east and south-eastwards; this fault may be observed for some distance and forms one of the great structural features of Baluchistán.

Lala Kishen Singh was engaged in systematically collecting fossils from certain beds described by Mr. Oldham in the paper quoted above; in the end a very valuable collection of fossils has been brought together, which have since been examined and described by Dr. Noetling. The description will be published in the Palæontologia Indica as soon as the numerous plates can be lithographed; the manuscript is ready for the press.

The general result fully justified my original opinion that there is quite a sharp

division between the cretaceous and eocene strata. The examination of the fossils proved also the existence of a distinct neocomian and below it, of a jurassic horizon. A local unconformity occurs above the neocomian.

The section at Mazár Drik, which is merely a type of numerous similar sections, is as follows in descending order:—

Middle / Lower Eocene	6 Shales and sandstones. 5 Grey limestone beds with *nummulites*.
Upper Cretaceous	4 Calcareous grit, shales and limestone with an abundant fauna of *cephalopods, echinoids, corals, foraminifera*, etc. 3 *Belemnite* bearing series of shales and limestone beds.
	Local unconformity.
Neocomian	2 White and grey limestone with *belemnites*.
Upper Jurassic	1 Hard grey, thick-bedded limestone with a rich ammonite fauna.

In the spring of 1894, I instructed Kishen Singh to survey the area south and south-east of the Zarghún and south of the Harnai and Khóst hills on sheet 21-$\frac{\text{SE}}{4}$ of the Baluchistán survey, which he did satisfactorily,—in all 590 square miles.

I myself continued the work, which I had begun during the previous field-season; the ranges which divide the Quetta valley from the Pishin and the Kójak range were examined, and several traverses were completed, to settle the question of structure of these ranges. But there is still much to be done and it will require at least one more season's work to fill in the gaps on our geological map of the country west and north-west of Quetta. The first 4½ months of 1894 I devoted to the study and survey of the ranges which inclose the western Zhób valley, and especially the mass of hill-ranges between Loralai and Khanazai. This was a continuation of my previous field-season's work and the result is a fairly accurate geological survey of about 3,400 square miles, completed during the greater part of two seasons. In this part of Baluchistán, I could distinguish the following divisions of strata in descending order:—

Recent	(11) Alluvium; wide-spread deposits of sandy clays, conglomerates, and also in places, blown sands, which generally pass up imperceptibly from the next older formation.
Seistán formation Pleistocene	(10) Red and white sandy clays with sandstone and conglomerate beds, with much gypsum in layers and strings.
Miocene and pliocene	(9) Sandstone, shales, and conglomerate of the ordinary Siwalik type; fossil bones and casts of large *gastropods*.
Younger Eocene and Miocene	(8) Great thickness of sandstone beds, very like the Siwaliks in character, but with occasional limestone partings, which contain marine fossils.

Eocene.	Great development of basic igneous rocks. Intrusions of later date.	(7) Concretionary limestone and shales with fossil. (6) Sandstones, shales, and clay. (5) Thick limestone with *nummulites*.
Upper Cretaceous.	Interbedded basic rocks; gabbro, tufa.	(4) Limestone with *Sphenodiscus*, *Cardium Beaumonti*, etc , etc. (3) Shales and limestone with *belemnites*.
Neocomian		(2) Thick limestone with neocomian fossils
Jurassic		(1) Massive limestone with jurassic fossils.

Along a great line of dislocation which runs along the Chinjan and Yusuf Kats valleys, I have met with what I must consider genuine "blocs exotiques,"—of carboniferous and triassic rocks, bearing fossils. The dislocation is characterized by intrusions of basic rocks which obscure the position of these "blocs." It is hoped that more evidence of the same will be forthcoming during the next field-seasons.

One of the most remarkable features of Baluchistán geology is the association or igneous rocks with the upper cretaceous and the lower and middle part of the eocene deposits. The first outburstl of basic rocks, as far as can at present be ascertained, occurred in later cretaceous times; at least evidence of *intrusions* only have been met with in the jurassic beds, and even the lower part (limestones) of the upper cretacious seems free from interbedded igneous rock, but on the other hand these beds show locally great alteration near intrusions of the latter examples: Kach near Quetta, Gwál and other localities in the Zhób valley. The earliest evidences of contemporaneous igneous action occur in the upper cretaceous belemnite beds. This is seen clearest in the upper Zhób valley, especially near Gwál. Certain large areas of Baluchistán (south of Hindu Bágh and Kójak range) are entirely made up of great outbursts and spreads of basic igneous rocks, with gabbro and serpentine, associated with a few sedimentary beds, which are much altered in places and quite schistose in some. It is hardly possible to divide this complex of rocks, as precisely similar conditions seem to have continued right into middle eocene deposits. The higher portion of this facies, which may be compared to the Flysch formation of Europe, especially as developed in the Island of Elba,—contains a few beds of limestone which yielded *nummulites*, thus limiting the duration of igneous action to the period between the deposition of upper cretaceous and middle eocene beds. Quite unaltered limestone with upper eocene (Spintangi) fossils overlies the igneous facies of the northern Zhób and of the Kójak range. All trace of igneous action seems to have died out during that epoch.

The Kójak formation of shales, limestones and tuffaceous rocks,—in places quite schistose—I considered to be tertiary in 1880 (Memoirs, Vol. XVIII) and later in 1884 (Records, Vol. XVII, page 59), as possibly cretaceous; probably both views are correct to some extent, and they may represent the igneous facies ranging from the upper cretaceous belemnite shales to middle eocene, and the formation may be a continuation westwards of the upper Zhób rocks. They are also associated with some irregular beds of limestone which contain large *nummulites*.

Connected with this great volcanic outburst are acid rocks, chiefly of the granitic family, which form part of the Khwája Amrán, and these may have been amongst the earliest eruptions which took place there.

Burma. Baluchistán. Dr. Fritz Noetling.

There are still a few questions of structural importance involved in the Yenangyoung oil-bearing tract and to clear up the same, Dr. Noetling was sent to Burma during this field-season. An exhaustive report on the oil-region will be brought out by him shortly.

During the hot weather and rains of last year Dr. Noetling examined and described the fine collection of cretaceous and jurassic fossils from Baluchistán which will be published as series XVI of the Palæontologia Indica.

Economic Geology.

During 1894, several officers were employed in practical investigations only, but in all cases where useful minerals were come across by the other parties engaged in field work, such occurrences have also been reported on.

Mr. LaTouche was during the past year, and is still, engaged in the trial boring for petroleum at Sukkur. Mr. Middlemiss has been engaged in the examination of the corundum and magnesite deposits of Madras.

Mr. Holland was employed in reporting on the Gohna landslip and has since been engaged in making numerous assays of minerals and rocks.

Mr. Smith surveyed the so-called "Quetta" coal-area, and has prepared a report which will be published. Dr. Fritz Noetling was deputed to report on the working of the Dandote and Warora coal-mines and has issued his reports on the same. He is now at Yenangyoung in Burma in order to finish his investigations of the oil-fields.

Mr. Grundy, the Inspector of Mines in India, has issued his first report for the year ending 1st July 1894, which has been printed and published. He has since inspected the mines in Mysore, Central Provinces and Rewah, and will proceed to Hyderabad (Dekkan), the Punjáb and Baluchistán.

Mr. William Anderson has been posted to Chota Nagpur to report on the supposed metalliferous belt of rocks.

Amongst the notes on useful minerals made by officers engaged in scientific surveys only, may be noticed reports by Mr. Bose on iron-ores, pockets of manganese, traces of copper and veins of argentiferous galena (61·60 per cent. lead and over 7 oz. of silver to the ton) in the Rewah State.

Mr. Datta reports on considerable quantities of an iron-ore in the Sone Valley, which is used locally for iron-manufacture.

Publications.

Considerable advance has been made in the publication of the Palæontologia Indica. Dr. Waagen has at last completed Vol. IV of series XIII, which deals with the ammonites of the ceratite beds of the salt-range. It is illustrated by 40 quarto plates and will appear shortly.

Series XV of the Palæontologia Indica has been commenced, and will illustrate the large and most important collection of fossils from the Himálayas, embracing not only the specimens preserved in the Geological Museum in Calcutta, but also every known specimen found in the Himálayas and preserved in the various European museums. Part 2 of Vol. II of this series is completed, and will appear shortly, illustrated by 31 quarto plates, descriptive of the Muschelkalk fauna of the Himálayas. Several other parts are in preparation.

Memoirs, Vol. XXV, on the geology of the Bellary district by R. B. Foote, is nearly ready for publication, and the final sheets are being passed for the press.

Vol. XXVI on the geology of Hazára by C. S. Middlemiss is in the press, and will appear shortly.

Vol. XXVII, Part 1 on the miocene fossils of Yenangyoung by Dr. Noetling, is in type and will shortly appear; Part 2 on the oil-fields of Yenangyoung is in manuscript, but will be ready for publication shortly after Dr. Noetling returns from Burma.

Museum and Laboratory.

Mr. Holland has re-arranged and labelled the collection of minerals to correspond with the more modern classification adopted in the new edition of Mr. Mallet's guide which has been re-written by Mr. Holland for the use of students. He also described a large number of rock specimens as contributions towards the work of classifying and arranging this portion of the collection. Where the description of the specimens has given promise of results of more than local petrographical interest, Mr. Holland has taken the opportunity of college vacations to work out their characters more fully in the field. In this way we have obtained a fairly comprehensive account of the distribution, and contact effects in the Bengal coal-fields of varieties of some new types of the remarkable group of peridotites. Amongst these the mica-peridotites which frequently contain anthophyllite and chromite are, from the excessive amount of apatite which they contain, most exceptional types amongst the known igneous rocks of the globe. The occurrence of these peridotites, which have now been found breaking through the lower Gondwana series in all the Bengal coal-fields, forms an interesting comparison with the peridotites which are similarly intrusive in the carbonaceous rocks of about the same age in South Africa. The large number of specimens of the peridotites and the altered and associated sedimentary rocks form a most instructive series in the Museum. In making this collection and in tracing out the field relations of the rocks, Mr. Holland has received most valuable help from Dr. Saise, Manager of the East India Railway Company's collieries at Giridih. (A detailed description of these rocks appears in Part 4 of Vol. XXVII of the Records).

Mr. Holland has described another new type of peridotite from the district of Manbhum which differs from previously known ones in containing hypersthene associated with olivine, augite, biotite and hornblende. (Records, Vol. XXVII, part 4.)

The mode of occurrence of the rare mineral columbite has been examined at Pananoa near Nawadih, East Indian Railway. Mr. Holland has found it in lumps imbedded in the quartz of a very coarse grained pegmatite dyke, intruded into a mica schist, which is crowded with tourmaline crystals.

The list of assays and determinations made in the laboratory has been published in the previous volume of the Records.

The work in the Museum was naturally interrupted during the early part of the year by Mr. Holland's absence at Gohna and Naini Tal, but he attributes the satisfactory progress which has been made largely to the valuable work done by the Museum Assistant, Mr. T. R. Blyth.

Whilst so much progress has been made in the mineral gallery of the Department, it is much to be regretted that the palæontological collection is in a most unsatisfactory state, both as regards arrangement of specimens and condition of the labels and cases. But this is entirely owing to the long absences of the Palæon-

tologist of the Survey, who for some years past has been engaged on entirely different work, such as reporting on the mineral resources of Burma and the inspection of collieries in India. But it is hoped that he will be able to devote himself to more scientific work in future. A good beginning has been made by him in describing the miocene fossils of Burma and the cretaceous collections from Baluchistán, and we may reasonably hope to get the Palæontological Museum into order during the next two years.
There is much need of an efficient Assistant in that branch of the Department.

Library. The additions to the library amounted to 1,756 volumes, of which 777 were acquired by presentation, and 979 by purchase.

C. L. GRIESBACH,
Director, Geological Survey of India.

CALCUTTA,
The 31st January 1895.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1894.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—John Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Bataviaasch Geonootschap van Kunsten en Wetenschappen.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
" K. Preuss. Acad. der Wissenschaften.
" K. Preuss: Geologische Landesanstalt.
BOLOGNA.—Reale Accademia delle Scienze dell' Istituto.
BOMBAY.—Meteorological Department, Government of Bombay.
" Natural History Society.
" Royal Asiatic Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Schlesische Gesellschaft fur Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australia.
" Royal Society of Queensland.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Acad. Roy. des Sciences.
" Société Belge de Geographie.
" " Roy. Malacologique de Belgique.
BUDAPEST.—Kön. Ungarische Geol. Anstalt.
BUENOS AIRES.—Acad. Nacional de Ciencias en Cordoba (Republica Argentina).
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
" Asiatic Society of Bengal.
" Editor, Indian Engineering.
" " The Indian Engineer.
" Indian Museum.
" Meteorological Department, Government of India.
" Royal Botanic Garden.
" Survey of India.
CAMBRIDGE.—Philosophical Society.
" University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Verein für Naturkunde.
CHRISTIANIA.—Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Kong. Danske Videnskabernes Selskab.
DEHRA DUN.—Great Trigonometrical Survey.

DES MOINES.—Iowa Geological Survey.
DRESDEN.—Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
" " Dublin Society.
EDINBURGH.—Geological Society.
" Royal Scottish Geographical Society.
" " Scottish Society of Arts.
" " Society.
FLORENCE.—R. Biblioteca Nazionale Centrale di Firenze.
GLASGOW.—Glasgow University.
" Philosophical Society.
GOTHA.—Editor, Petermann's Geographische Mitthcilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALLE.—Academia Cæsarea Leop.-Carol. Naturæ Curiosorum.
HAVRE.—Société Géologique de Normandie.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LEIDE.—École Polytechnique de Delft.
LEIPZIG.—Verein fur Erdkunde.
LIÈGE.—Société Géol. de Belgique.
LILLE.—Société Géologique du Nord.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Museum.
" Geological Society.
" Iron and Steel Institute.
" Linnean Society of London.
" Royal Geographical Society.
" Royal Institute of Great Britain.
" Royal Society.
" Society of Arts.
" Zoölogical Society.
MADRID.—Sociedad Geografica de Madrid.
MANCHESTER.—Geological Society.
" Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
" Royal Society of Victoria.
MILAN.—Societá Italiana di Scienzé Naturali.
MOSCOW.—Société Imp. des Natur.
MUNICH.—Kon. Bayerische Acad. der Wissensch.
NAPLES.—Reale Accademia delle Scienze Fisiche e Matematiche.
NEWCASTLE UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, "American Journal of Science."
NEW YORK.—Academy of Sciences.
OXFORD.—University Museum.
OTTAWA.—Geological and Natural History Survey of Canada.
PARIS.—Editor, Annuaire Géologique Universel.
" Commission des Mines.

PARIS.—Ministere des Travaux Publics de la Carte Géologique de la Fiance.
„ Société de Geographie.
„ „ Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Obseivatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Scienze.
„ „ Comitato Geol. d'Italia.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Comité Géologique.
„ Russische Mineralogische Gesellschaft.
SALEM.—Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Bianch of the Royal Asiatic Society.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—L'Institut Royal Geol. de la Suede.
„ Kongliga Svenska Vetenskaps Akademie.
SYDNEY.—Australian Museum.
„ Department of Mines and Agriculture, New South Wales.
„ Geological Survey of New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TOKIO.—Deutsche Gesellschaft für Natur und Volkerkunde.
TORONTO.—Canadian Institute.
TURIN.—Reale Accad. delle Scienze di Torino.
„ Regia Universita di Torino.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissenschaften.
„ K. K. Geographische Gesellschaft.
„ K. K. Geologische Reichsanstalt.
„ K. K. Naturhistorisches Hof-Museum.
WASHINGTON.—National Academy of Sciences.
„ Smithsonian Institution.
„ United States Geological Survey.
„ „ „ Mint.
„ „ „ National Museum.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Naturforschende Gesellschaft.
The Governments of Bengal, Bombay, India, Madras, and the Panjáb.
The Chief Commissioners of Assam, Burma, and the Central Provinces.
The Residents, Hyderabad and Mysore.

The Cretaceous Formation of Pondicherry by H. WARTH, D. SC., (Tübingen), *Deputy Superintendent, Geological Survey of India.*

The area which I was deputed to examine during January and February 1894, had last been visited by the late Mr. H. F. Blanford in 1860, and was described by him in Vol. IV, p. 156 of the Memoirs. It is situated between the Red Hills of Pondicherry on the south-east and between what Mr. Blanford called the Tirvukarai ridge on the north-west, and is bounded on the south-west by the alluvium of the Ariankupam river. The total length is about 8, and the width 4 miles. A large surface of this ground is occupied by numerous tanks or artificial reservoirs for rainwater used for irrigation. Most of the area consists of level and cultivated fields, amidst which are a few isolated exposures of rock *in situ.* It is not nearly as favourable for study as are the cretaceous sections near Trichinopoly; there the exposures of strata on eroded patches measure square miles, whereas in the Pondicherry area they amount to acres or even square yards only. This great paucity of exposures has been repeatedly pointed out by Mr. H. F. Blanford, and if, notwithstanding this, the first explorers, Messrs. Kaye and Cunliffe obtained such large numbers of valuable fossils in 1840, it will be shown further on how this may be accounted for.

Mr. H. F. Blanford showed that the cretaceous strata may be separated into two distinct divisions: the lower he named the Valudayur group, which hitherto has been considered to be equivalent to the Utatur group of Trichinopoly, whilst the upper series he found to be identical with the Ariyalur group of Trichinopoly.

Considerable confusion has taken place in the collections made in Pondicherry, and the object of my visit to that area was not only to obtain a large number of fossils, but to establish them in the various horizons. I have succeeded not only in separating the fossils according to the two main divisions, but I have been able to distinguish three successive horizons in each of these divisions. We have, therefore, altogether 6 horizons from which fossils have been obtained, the three lower of which constitute Mr. H. F. Blanford's Valudayur group, whilst the three upper ones are what he accepted as Ariyalur group. As will be shown later on, the whole of the strata must now be considered as Ariyalur group.

The bedding of these horizons is either horizontal or a gently dipping towards south east. The general lithological character of all the beds is that of sand or sandy clay with calcareous nodules or concretions which are scattered throughout the whole formation. Only the uppermost horizon contains a continuous thin layer of limestone in addition to concretions.

Horizon A.

Horizon A is the lowest sub-division and appears on the surface as a strip 2 miles wide. It is separated from the Tirvukarai ridge by a band of alluvium $1\frac{1}{2}$ miles wide which conceals all outcrops. Going from north-west to south-east, the first indication of the horizon consists of white sands with nodules of one foot thickness. These nodules or concretions contain traces of annelid channels only. They are also stained with dendritic manganese. The localities examined are well-exacavations, $\frac{1}{4}$ mile east-south-east of Lingaredipaliam and 1 mile north-east of Katarampokam.

Next in ascending order we observe yellow sands with gravel, 1 mile east-

north-east of Katerikupam in the bed of the canal, and in the ravine 1 mile north-east of Vanur. The latter place is referred to by Mr. H. F. Blanford on page 157 of his Memoir.

Lastly, we have sandy clays with large concretions, which contain; annelid casts, they have a diameter of ¼ inch, and some were up to 6 inches in length. They are usually curved. The concretions consist of crystalline calcite with a distinctly botryoidal surface. They are usually somewhat lenticular, 2 feet thick, and of 3 feet diameter. I have searched for them in vain in the neighbourhood of the Ariankupam between Valudayur and Muterampatu, but the concretions are well exposed at the following three localities which are on the same strike, from south-west to north-east:—The first is near Katerikupam, where the concretions show along a length of over ½ mile of the canal excavation. The blocks had about 2 feet diameter and the surfaces were decidedly botryoidal, proving their concretionary origin. The second locality is about ⅜ miles south-west of Vanur; the concretions are shown very clearly in several square wells. They form layers which have a slight inclination towards the south-east. Many of the lenticular concretions had about 1½ feet thickness and 3 feet diameter with botryoidal surfaces. In one well were so many concretions and so close together that they presented the appearance of a continuous bed of limestone, 2 feet thick. The concretions contain numerous annelid burrows. I broke up one of the blocks entirely without finding a trace of any fossil. In the neighbouring fields were also scattered blocks of the same kind. Near the village of Wattai close by, is a large square tank which is lined with the same blocks said to have been derived from the excavated tank bed. Many blocks of the concretions from horizon A are also seen in the lining of other tanks in the neighbourhood, for instance at Vanur. But in the latter many stones had been used, which must have been brought from near Saidarampet in French territory, and belong possibly to horizon E, and are usually fossiliferous. It is not easy to distinguish always the different blocks from each other. But those from horizon A have no fossil shells and are botryoidal, whilst certain fossils show others at once to have been derived from horizon E. The third place is the best of all the exposures. It is immediately south of the village of Andipaliam, where many concretions are exposed on the surface. One of them was 2 feet by 4 feet by 6 feet. The concretions formed layers with a moderate dip to the south-south-east, many of them were also washed out of the matrix, but most probably are very near their original site. Some of the concretions contained quartz pebbles about 2 inches in length arranged in layers.

I observed also some concretions about half a mile south-east of Olundiapati, in which I have not found any fossil, but which I am inclined to include in horizon A.

Horizon B.

The next higher horizon B contains fossiliferous concretions and has also yielded some fossils from the sandy matrix. I include herein the exposure of yellow sands in a tank-bed, 1 mile south-east of Vanur. At that place I found many minute bivalves and a few distinct *Baculites vagina*. On the Vanur Pondicherry road, 1 mile north of Saidarampet, small bivalves occur in a white sand, which I include in B, although it is in contact with scattered blocks of horizon E. I also include with B large, slightly fossiliferous concretions and nodules, 1 mile south-south-east of Pulichapaliam. In the road ditch and in

some wells east of the road, I found fossiliferous concretions of large size, of which one has yielded a small *ammonite*.

Horizon C.

Horizon C is the most important of all, as it seems most probable that from it were derived the cephalopods which Messrs. Kaye and Cunliffe obtained about the year 1840. The spot from which most of these fossils appear to have come is north-north-east of Valudayur and north of Tutipet. It is from this place that I obtained the best fossils of horizon C, but some I found further north-east close to the village of Rautankuppam. I found in this horizon four small *ammonites*, several species of *Hamites*, *Baculites vagina* in numerous well preserved specimens, many *lamellibranchiata*, *gastropoda*, etc. The list at the end of this paper refers to preliminary identifications by Dr. Kossmat.

The fossils occur in blocks which are not *in situ*, but washed out of the alluvia ground, and are largely used for building purposes, so that the supply is really limited. I have now used up all the loose blocks which I could see, and I doubt whether more will be found for a considerable time to come. Mr. H. F. Blanford considered the place already exhausted, as will be apparent from his remarks on pages 154, 155, 156, 158, 163, Memoirs, Vol. IV, and page 2 of his account of Cretaceous Cephalopoda in the *Palaeontologia Indica*.

Mr. Blanford referred at some length to the ridge east of Valudayur on which he traced the boundary between his Valudayur group and the overlying Ariyalur group. This ridge is not a very prominent object in the landscape, and some of the exposures on it, which Mr. H. F. Blanford described, must since have disappeared. If the Topographical Survey map had been provided with contour lines, this ridge as well as the Tirvukarai and Red hills ridges would be clearly shown, but although this is not the case, the ridge in question is marked by the space which it occupies between two rows of irrigation tanks, and a line drawn on the map from Tutipet to Akasampatti travels along the centre of the ridge. It rises about 115 feet above the sea and thus about 45 feet above the cretaceous area to the north-west of it and 89 feet above the level of the great Usteri tank lake to the south-east. Near Tutipet and Valudayur, the north-west base and part of the slope of the ridge comprises horizon C. Towards north-east the ridge merges more or less into the more elevated country, and the exposure of horizon C near Rautankupam is on nearly level ground. As will be seen hereafter, the south-east slope of the ridge about Tutipet, Karasur and Saidarampet coincides with the harder beds of the horizon F, and it is very probable that these limestone banks have been the cause of the preservation of the ridge.

Horizon D.

The horizon D is characterized by a continuous bed of sandy shale, several feet thick, which is full of casts of shells, most of them those of *lamellibranchiata*, *Trigonoarca Galdrina*, *Macrodon Japeticum*, *Alectryonia ungulata*, etc. Others will be found on the list at the end. I also found a few *ammonites* and *Baculites vagina* and some specimens of *nautilus* two feet in diameter. A few specimens of *terebratula* were also found in this horizon, also some *corals* and *echinoidea*. Small fish teeth were numerous.

A fact of importance is the wholesale conversion of shells into phosphate, or rather the production of interior casts of shells consisting of rich black phosphate.

Some of the casts show also the impression of honey-combed cells one-fiftieth of an inch in diameter, most likely due to bryozoa. In this same stratum are also numerous concretions of light brown colour, which are likewise strongly phosphatic; they are of irregular shapes, resembling some organic structure.

I found three very clear exposures of this horizon. The first in a well, a quarter of a mile west-south-west of Tutipet, the second is *in situ* on the surface of the road a quarter of a mile north of Karasur, the third is in a well a quarter of a mile west of Rautankupam on the west side of the Tindivanam Pondicherry road. A small exposure was also noted in a well, a quarter of a mile north-west of Royapudupakam. In the Rautankupam well the sandy bed, which contains the casts of shells, is also partly replaced by concretions of one foot thickness, in which fossils occur.

Phosphatized shells are not found in any of the other horizons, with the exception of the lowest portions of horizon E. There are some phosphatic cores of light color in the centre of gastropods, in nodules of the upper part of horizon F. But these cores are of quite different appearance to the phosphatic matter in D, and in much smaller quantity. The black phosphatized shells are a sure indication of horizon D and the overlying portions of horizon E. They are seen in several places scattered over the fields mixed with other fossils, where no distinct exposures of the strata are otherwise seen.

Horizon E.

This horizon is important on account of the large number of nodules of shell limestone it contains. A very great number of the nodules have been utilized for tank revetments and buildings in the neighbourhood. Many were also used for walls, buildings and pavements in Pondicherry. The pavement shows all the various fossils of the horizon in sections. One fossil is especially very prominent and characteristic. It is a coral, *Cyclolites filamentosa*, which is seen in semicircular sections. *Exogyra ostracina* is also common. Owing to the systematic removal of blocks from the surface of the outcrop, it is generally difficult to trace the area of horizon E, but at a place near Karasur I still saw the blocks being quarried, and one very large deposit of blocks is exposed *in situ*. There is also an outlier of this deposit consisting of some 40 blocks, at a point 1 mile north of Saidarampet. The worn surfaces of the blocks show sections of numerous fossils, which contrast strongly against the brown matrix. Besides *gastropoda* and *lamellibranchiata* in great numbers, the sections also show the semicircular or crescent shaped outlines of *Cyclolites filamentosa*, which coral is most characteristic of horizon E.

The wall of a tank near the village of Royapudupakam yielded numerous fossils as has already been pointed out by Mr. Blanford. Amongst them I collected *Exogyra ostracina*, *Alectryonia ungulata*, *Euptycha larvata*, *nautilus*, *etc.* Some of the fossils are also found in horizon D and with them were also some black phosphatic nodules.

Horizon F.

The uppermost horizon is characterized by fucoid casts, which are cylindrical and about three quarter of an inch thick and generally in broken pieces of about five inches length; some of these casts are bifurcated. They are much used for lime burning, along with calcareous nodules found in the same bed. The latter are about two inches diameter and

contain spiral *foraminifera* of minute size; they are dug up from the soil which overlies some of the fucoid limestone.

The same yellow, crystalline, somewhat sandy limestone was found exposed at the Usteri canal, one mile south-south-east of Valudayur and half a mile along that canal towards south-east; at four places on the way thence to Kadaperikupam; at the kilns half a mile south-west of Kadaperikupam; at Kadaperikupam; at Saidarampet; at the kilns quarter of a mile east-north-east of Saidarampet; half a mile west of Akasampati; quarter of a mile east-south-east of Akasampati; quarter of a mile south of Wattampalliam (French part of village called Sanjiverampet), and lastly in the bed of a large open tank near Royapudapakam.

The limestone is the only continuous bed of hard rock in the Pondicherry cretaceous. At the Usteri canal I estimated the total thickness to be five feet of limestone, with partings of sand. At Saidarampet a solid bed of limestone showed two feet thickness with a dip of four degrees south-east.

Most of the fossils are obtained from the overlying sands. Amongst them are some very characteristic corals (*Coryophylla arcotensis*, *Cyclolites conoidea*), *Teredo* tubes in abundance and very large gastropods (cones of one foot length), *Nautilus serpentinus* and one nautilus with a very sharp keel, apparently a new species.

The limestone dips generally towards south-east, the surface of the country coinciding with the dip slope. Above the limestone, clays and sands with nodules continue. One clay bed with layers of nodules has already been mentioned as containing some shells with light coloured phosphatic cores. In this bed remains of a turtle were found. Still higher up in the series large concretions of two feet diameter are seen in an excavation one mile north of Tirusitambalam (at the road fork). Near Tirusitambalam I noticed yellow clays with minute bivalves, and similar clays continue up the side of the Red hills ridge. These were no doubt the upper-most cretaceous deposits mentioned by Mr. H. F. Blanford, page 160, Vol. IV.

These six horizons represent the whole sequence of the cretaceous strata.

A line of section.

With the exception of horizon F the exposures of the strata are very few and it would be difficult to find a continuous sequence. But there is, however, a line of section, in which four horizons are well represented and the other two at least indirectly. This is along the Tindivanam Pondicherry road. Starting at a place 12 miles from Pondicherry, we obtain a fair section along a straight road of about $4\frac{1}{2}$ miles length, along which exposures of most of the horizons are seen.

Dip of strata.

The general dip of the sequence of beds was given by Mr. H. F. Blanford as two degrees, which accords with my own observations.

Thickness.

The total thickness of the cretaceous rocks of Pondicherry may be about 900 feet.

Preliminary table of fossils.

The fossils obtained were sent to Vienna for determination and they have since been examined by Dr. F. Kossmat of the University of that city. He will describe the collection in detail, but has given the annexed preliminary list of fossils.

Preliminary List of Fossils.	Horizons.				
Caryophyllia arcotensis Forb.	...	...	...	...	F
Cyclolites conoidea Stol.	...	...	...	...	F
Hemiaster, n. sp.	...	...	D	...	...
Stigmatopygus elatus	...	C	...	...	...
Terebratula arabilis, Forb.	...	...	D	...	...
Alectryonia ungulata, Schl.	...	C	D	E	...
Exogyra ostracina, Lam.	...	...	...	E	...
Gryphaea vesicularis	...	...	...	...	F
Plicatula	...	...	D	...	...
Spondylus, n. sp.	...	...	...	...	F
Spondylus calcaratus, F.	...	...	D	...	...
Pinna cf. laticostata, Stol.	...	C	...	...	...
Modiola flagellifera, Forb.	...	C	...	...	...
Modiola polygona, Forb.	...	C	...	...	...
Macrodon Japeticum, Forb.	...	...	D	...	...
Trigonoarca sp.	...	C	...	...	...
Trigonoarca Galdrina, F.	...	C	D	E	...
Cyprina cristata, Stol.	...	...	D	...	...
Protocardium bisectum, Forb.	...	C	...	...	...
Panopaea orientalis, Forb.	B	C	...	...	...
Pholadomya caudata	B	C	D	...	...
Corimya pertusa, Stol.	...	C	...	...	...
Pharella obscura, Forb	B	C	...	...	...
Teredo aff. glomerana	...	...	...	...	F
Phasianella cf. conulata, Stol.	...	C	...	...	...
Euspira sp.	...	...	...	E	...
Euptycha larvata, Stol.	...	...	...	E	...
Nerita sp.	...	C	...	...	...
Nerita divaricata, Orb.	...	C	D	E	...
Turitella sp.	...	...	D	E	...
Cerithium, n. sp.	...	...	D	...	F

Preliminary List of Fossils.	Horizons.				
Nerinea, n. sp.	...	...	..	...	F
Cypraea Newboldi, F.	...	...	D	...	...
Cypraea sp.	...	...	D	E	...
Cypraea Kayei, Forb.	...	...	...	E	...
Rostellaria palliata, Forb.	...	C	...	...	...
Athleta purpuriformis, Forb.	...	C	...	...	...
Nautilus sp.	...	...	D	E	F
Nautilus aff. Bouchardianus	...	...	...	E	...
Nautilus cf. serpentinus, Blanf.	...	...	...	...	F
Nautilus sphaericus, Fort.	...	...	...	...	F
Lytoceras sp.	B	...	...	...	...
Hamites subcompressus, Forb.	...	C	...	...	...
Hamites indicus, Forb.	...	C	...	...	...
Hamites tennisulcatus Forb.	...	C	...	...	...
Ptychoceras sypho Forb.	...	C	...	...	...
Baculites, sp.	...	C	...	...	...
Bacolites vagina, Forb.	...	C	D	E	...
Desmoceras sp.	...	C	...	...	...
Pachydiscus ganesa, Forb.	...	C	...	...	...
Pachydiscus species	...	C	D	...	...

The fauna.

Dr. Kossmat intends giving a fuller description of the fossils later on, but I am authorized to state that he considers the Pondicherry cretaceous series to belong to the Ariyalur division. I may also remark here that these fossils have confirmed this conclusion, which Dr. Kossmat had already arrived at from other evidence; he had compared the original type specimens of the cepalopods of the Utatur and of the so-called Valudayur groups and had also discovered new points of agreement between the fauna of the Ariyalur group of the Trichinopoly area and the Valudayur group, and also with the cretaceous fauna of Natal. The Valudayur group will cease to be so distinguished and the horizons A, B, C, will have to be considered to be lower Ariyalur only

Some early allusions *to* Barren Island; *with a few remarks thereon, by* F. R. MALLET, F. G. S., *late Superintendent, Geological Survey of India.*

When writing the description of Barren Island that appeared in the twenty-first volume of the Survey Memoirs, I was unable to refer to any accounts of the Volcano earlier than that by Lieutenant Colebrooke, who saw it from a distance in 1787, and that by Captain Blair, who landed during a violent eruption in 1789[1]. The name 'Barren Island,' however, was not originally given by either of those observers: it had been applied before their time to the Volcano, which, by some, had also been called 'Monday' and 'High' Island. It was clear, therefore, that the island was more or less known before Blair's visit, and it seemed possible that some one or more accounts of it, by navigators who had seen, or even landed on it, might be in existence, and that perchance some allusions to its volcanic condition earlier than those mentioned above, might be on record. I have recently taken advantage of residence near London to try whether any such accounts could be found, and with this object in view, have made a somewhat laborious search at the libraries of the India Office, the British Museum, and the Public Record Office. The examination of a very large number of printed works and manuscripts has, I am sorry to say, not led to the acquisition of a corresponding amount of new information, and there can be little doubt that there still exist accounts which remain to be discovered. But the following records, however meagre, at least add something to our knowledge of the volcano.

Van Linschoten, 1595.

The earliest indication of the island being known, that I am aware of, is to be found in the original Dutch edition of Van Linschoten's[2] voyages[3]: this work contains two maps engraved in 1595, one of India and some adjoining countries, the other of the Malay Peninsula and archipelago[4]. The 'Andemaon' and adjacent islands are included in both, the configuration in one being identical with that in the other. 'Nacondaon' is placed in lat. 14° 20'. No longitudes are given, but the position is 90 miles[5] E. or E. ½ N., from the northern end of the Andamans. About 45 miles S. by E. from "Nacondaon" (Narcondam), in Lat. 13° 35', there is a nameless island which is much nearer the true latitude of Narcondam (13° 26') than that to which the name is attached, and it is probably a duplication of that island, through a discrepant, and more accurate, determination of its position.[6]

[1] Asiatic Researches, Vol. IV, p. 397.

[2] Erroneously printed "Linschten" in Memoirs, G. S. I. Vol. XXI, foot-notes to pages 264 and 285.

[3] "Itinerario Voyage ofte Schipvaert, Van Jan Huygen Van Linschoten naer oost ofte Portugaels Indien," etc., Amstelredam, 1596.

[4] Facsimiles of these maps (but with the Dutch titles, etc., rendered into English) are included in "John Huighen Van Linschoten, his Discours of Voyages into ye Easte and West Indies," London, 1598, a translation of the original work.

[5] Here, and elsewhere, the miles given are nautical ones.

[6] On a "Chart of the Bay of Bengal," contained in the "East India Pilot, or Oriental Navigator," and dated 1778, or nearly two centuries later than Linschoten's maps, "Narcondam of the Portuguese" is marked in Lat. 13° 47' and "High I. or Narcondam of the

A second small and nameless island is marked about 45 miles east of the Andamans, in Lat. 12° 25'. This is some 10 or 12 miles N. W. from the true position of Barren Island, for which, I think, there can be no reasonable doubt that it is meant, as there is no other land for which it can possibly be intended.

Linschoten makes no mention of having himself visited the Andaman Islands. In the titles of the above named maps it is stated that they were "perfectly drawne and examined with the most expert cardes of the Portingales Pilots," which suggests that the island just mentioned were inserted on Portuguese authority as the explorer who charted them thought Narcondam worthy of a name on the map. Perhaps if Barren Island had been in eruption, and thus specially attracted his attention, he would have attached one to it also.

On many charts of much later date than Linschoten's, no land near the position of Barren Island is indicated. Hence it was a new discovery to Captain H. Gough, when he sighted it in 1708.

Gough, 1708.

The log of his ship, the Stretham, is preserved at the India Office. On the 17th December of the year just mentioned, the following entry was made:—"Now at sunrise we see Land[1] from W. b. N. to N. W. b. N., at 7 o'clock ye squall being over we had an Island appearing thus" (small sketch given); "then ye other land bore from W. to N. W. by W. distance, I judge, 10 or 12 leagues. Now we have no drafts[2] that anything answer these bearings; therefore I commenced one From yo Lat. 11° which will include ye shoall,[3] to Lat. 14°, which will carry me to ye Cocos Islands; see the other side." The last sentence refers to Gough's M. S. chart,[4] on which the island, without any name, is marked in Lat. 11° 53', and 58 miles E. S.E. from the Andaman coast. It is about 23 miles south of the true position of Barren Island, an error which is probably due to the fact that while Gough obtained his latitude on the 16th by observation, that on the 17th was by "account." There is, however, a discrepancy between the log and the chart. In the former his latitude on the 17th is given as 12° 30', while on the chart his position at noon is marked in Lat. 12° 18'. If this difference were applied to the island, it would bring its latitude within 11 minutes of the correct one.

The island when seen was at a distance of 8 or 10 leagues to the E. S. E., and

French" 45 miles to the S. E. by E. in Lat. 13° 20'. On "a general map of the East-Indies" (1781), contained in the same Atlas, "Narcondam according to the Portuguese" is marked in Lat. 13° 45', and "Narcondam or High Island according to the French," 60 miles to the S. by E. in Lat. 12° 50'. The French Island is certainly not intended for Barren Island, although the latter, as previously remarked, has also been known under the name of High Island. (See remarks, further on, about the "Flat Islands," and *cf.* Memoirs G. S. In Vol. XXI, foot-notes to pages 264 and 285). I have not succeeded in finding any original accounts of the Portuguese or French observations.

[1] The Andaman Coast.

[2] The obsolete term for chart.

[3] The "Flat Rock, awash" of the Admiralty chart (lat. 11° 8'). Capt. Gough puts it in 11° 10', and on the 14th December writes :—Now as we rose from dinner we see Breakers N. N. E. of us nothing appearing above water. I suppose them 7 or 8 miles of as they broke high. We tacked. This shoall we find in our Drafts as to Latitude, but its laid not above 7 leagues off ye little Andemons and we see them not."

[4] Scale 3½ inches to 1° of latitude. A copy, on a reduced scale, is included in Dalrymple's Plans and Charts.

measures on the chart about 4 miles × 2, with the length perpendicular to the line of sight; but this was evidently a mere eye-estimate.

There is a rough free-hand sketch of the island in the log, from the point of view just mentioned, which represents it as a very high one,[1] with the culmination near the S. S. W. extremity, a nearly flat top inclining gently towards the N. N. E., and steep slopes at the ends exactly the appearance which Barren Island, at the present time, would have, if viewed from the same position,[2] except that the height, in proportion to the breadth, in the sketch,[3] is a good deal more than in nature. This is so obviously due to exaggeration, which might, perhaps, be almost expected in a rough outline evidently dashed off *currente calamo*, that it would be waste of space to raise the question whether the valcano really was much higher in 1708. Had such been the case indeed, the truncation of the ancient cone must necessarily have been far less than is implied by the sketch, and the latter would entirely fail to represent the facts.[4] There is no indication, in the sketch, of smoke[5] rising from the volcano.

Various observers.

Reference to the observations of several navigators may be found in a "Memoir of a chart of the Indian Ocean," 1787 (contained in the first volume of Darlymple's Nautical Memoirs), where at page 36 we read:—

"The Island, called *Barren Island* by Capt. Taylor and Capt. Justice, *Monday Island* by Cheyne, from old Draughts; and *Alto* by Capt. Baker and C. Alves[6] is in

Lat.	12°·20′ N. by	C. Mills, 1758.
	12 22	Alves, 1760.
	12·20	Justice, 1771.
	12·20	Taylor, 1780.

Long. by Capt. Taylor's observations of Sun and Moon 93° 10′E. from Greenwich."

Cheyne, 1748.

The log of Capt. Cheyne's ship[7] (the Lapwing) shows that Cheyne passed "Monday" (Barren) Island, at the close of October 1748, and saw it from various points of the compass, but he made no nearer approach than 8 or 9 leagues. His observed latitudes on the 28th and 29th, combined with the bearings and estimated distances of the island, respectively made it in lat. 12° 6′ and 12° 16′. He remarks that "this by some is called Monday Island, but we have no account of it in the draught."

[1] The greatest elevation, as measured by Capt. Hobday in 1884, is 1,158 feet: therefore allowing for curvature and refraction, the island at a distance of 8 leagues would rise more than 700 feet above the horizon, while at 10 leagues it would still rise nearly 500.

[2] *cf.* Capt Hobday's sketch, in the corner of his map (Memoirs, Vol. XXI), taken from nearly the same bearing, but much nearer the volcano.

[3] One to five, which, under the circumstances of distance mentioned, would indicate a height of more than 2,000 feet if the sketch had been drawn accurately to scale.

[4] *cf.* Remarks, in the succeeding paper, as to the probable antiquity of the truncation.

[5] A convenient term, and quite as accurate as cinder and ash, in connection with volcanoes.

[6] "Barren Island, still smaller than Narcondam, is called likewise *Monday Island*; and by the Portuguese *Ilha Alta* (High Island)." 'The Oriental Navigator,' by J. Purdy, London, 1826, page 350. The information in this work about the Andamans is of somewhat old date and "extracted chiefly from Capt. Richie's account."

[7] India Office Records.

In the year 1758, Captain Mills, of the Drake, noticed "Land even with the water" in Lat. 11° 12′, and "he says the land and (Alto, which he calls) *Arracondam*, bears of each other N. b. E. ½ E. and S. b W. ½ W. distant 21 leagues,"[1] which makes the latitude of Alto (Barren Island) 12° 12′, or within 4 minutes of the now accepted value. This quotation is of interest from the name Arracondam (presumably a corruption of Narcondam) being applied to *Barren Island.* Although I do not think Captain Mills' application of the name can be taken as proving anything, as he probably so used it through imperfect imformation, still the point is worthy of notice in connection with the origin of the term Narcondam alluded to in my memoir on the volcanoes.[2]

Mills, 1758.

I have not met with any record by Captain Alves or Baker. The discovery of a dangerous rock was reported by Captain Justice in 1771, which he describes in some detail[3] and at the conclusion says "Imagining I was to the westward of the Little Andaman I stood to the N. N. E.—ward in order to get its true place, but on the 2nd November, at 6 o'clock in the morning, I was surprised to see *Barren Island;* it lays by my account, not allowing the current, to be 20 miles to the westward of Barren Island[4] in the latitude of 11·07 or 11·12."[5]

Justice 1771.

The following remarks by Captain Taylor[6] of the Ship 'Ceres' are perhaps worth reproduction in full, as illustrative of the inaccuracy and uncertainty that prevailed about Barren Island until late in the last century:—

Taylor 1780.

× × × × ×

"January 12" (1780), "per medium of 13 good sights of the longitude found ourselves in 93° 36′ longitude from Greenwich, which is 1° 33′ W. since last sights and by the charts is nearly the longitude of the Islands, laid down in 12° and 11° 30′ N. Lat. by the name of *Barren Island.* Kept a very good look out in the night and sounded as per log; next morning at daylight saw a pretty large Island bearing N.E. ½ E., 10 leagues, the ext. of the *Andamans* (just in sight) from W.N.W. to S.W. by S., 9 or 10 leagues. Till noon, that we had a good observation, could not determine whether the Island in sight was the northernmost *Barren Island* or *Narcondam;* we observed in 11° 59′ N., the lat. of the northernmost *Barren Island* as laid down in the charts; the Island bearing N.E. by N. between 8

[1] Memoir of a Chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[2] Page 284.

[3] He was not, however, the original discoverer of the danger, which was seen by Gough in 1708, and alluded to by him as previously known.

[4] *i.e.* the rock is 20 miles west of the meridian of Barren Island.

[5] M. S. Bengal Public Consultations, India Office Records; and Memoir of a Chart of the Indian Ocean, 1787, (*op. cit.*), p. 36. I may mention here, incidentally, that the earliest illustration of Narcondam I have met with, is to be found on a "Chart from Negrais to the Island Carnicobar, by John Richie, 1771" (Dalrymple's Plans and Charts), as might be anticipated in respect to an extinct volcano; this sketch ("Narcondam, bearing E. by S. distant 7 miles"), shows no perceptible variation from the present outline. On this Chart Barren Island is not indicated.

[6] Dalrymple's Nautical Memoirs, Vol. II.

and 9 leagues distant which makes it come nearest the lat. of Barren Island. A day or two afterwards by a very good observation within 2 or 3 miles from the northern end of it, find its latitude to be 12° 20′ northern (21 miles to the northward of its situation upon the Charts)[1] and its longitude, by several very good observations of the Sun and Moon, to be 93° 10′ E. from Greenwich.

The nearest of the *Andaman* Islands we could see bearing S. W. by W. from it 18 or 20 leagues. As for the southernmost *Barren Island* we concluded that it did not exist, or if it did, that it must be very erroneously placed in the charts, for the day after we saw *Barren Island* we were set to the southward in endeavouring to pass to the eastward of it, and at noon had the Island bearing from N.b.W. to N.N.W., 12 leagues and observed in 11° 48′ N., which is nearly the southernmost *Barren Island* (as laid down) notwithstanding which, saw no such Island although the weather was very clear; since which time I was informed by the Captain of a Portuguese schooner that he had seen both the Islands, the southernmost being situated much further to the westward than laid down.

"I likewise have it from good authority that Captain Sharrington of the Bahar country ship saw the rocks under its ship's bottom and sounded in 4 fathoms *Barren Island* being N.N.W. 5 or 6 leagues. In the charts there is some dangers laid down[2] to the southward of the southernmost *Barren Island*, I imagine it is meant to be placed to the southward of the northernmost, as I think it seems doubtful whether there are but one or two Islands. The Island of *Narcondam* bears N. by E. ½ E. 23 leagues distant, from *Barren Island* in lat 13° 26′ N. and Long. 93° 30′ E. from Greenwich, both ascertained from very good observations. The Island *Narcondam* and *Barren Island* appear very different when seen at some distance; so that, independant of their latitudes, with a simple sketch of each Island a man could be at no loss readily to know the one Island from the other. *Narcondam* makes like a sugar loaf, quite flat at the top, and may be seen at least 18 leagues from the mast head, for we saw it 13 or 14 leagues from the poop pretty high out of water, the weather rather hazy; this distance may be depended upon as its calculated from the bearings and differences of latitude.

"*Barren Island* appears much longer, but not quite so high; the watermost ext, is the highest, and makes with a peak, descending to a low point to the eastward, although when you come near it, it seems of an equal height, with a peak at each end; it may be seen at least 15 or 16 leagues, for it was high out of the water when we saw it bearing N. by W. 12 or 13 leagues distant per calculation."

One Island, or two?

In explanation of Captain Taylor's surmise, whether one Barren Island, or two, existed, I may say that in various atlases of the eighteenth century[3] two small islands are marked, one nearly due north of the other, on a meridian some 50 miles east of (what appears to represent)

[1] *Cf.* Gough's observations. F. R. M.

[2] That reported by Gough and Justice? F. R. M.

[3] *e. g.* "Le Neptune Oriental ou Routier général des Côtes des Indes Orientales," Paris, 1745 (*Isles Rases*). "Carte de L' Inde par le Sr. D'Anville, dated 1752, contained in the same author's "Géographie Ancienne Abrégée," 1769 (*Isles Rases*). "A New Directory for the East Indies" (based on Le Neptune), 6th edition, London, 1767 (Barren Islands). "The East India Pilot or Oriental Navigator," 2 charts dated respectively 1778 (Flat Islands and Barren Islands—both names given) and 1781, Flat Islands.

the South Andaman. The latitude of one varies from 11° 21′ to 11° 30′; that of the other from 11° 59′ to 12° 8′. In the French Atlases these are called the '*Iles Rases*,' while in some of the English they are called the 'Barren Islands' and in others the 'Flat Island.' However, one or two of these names came into use (possibly through some mistranslation from one language into another), the northern *Isle Rase*, as charted, agrees very fairly in position with Barren Island, and cannot be intended for anything else. What the southern *Isle Rase* was intended for I do not know. It was not meant for the rock east of Duncan's passage,[1] for in some Atlases, (*e.g.*, Le Neptune Oriental), the latter is marked *in addition to* the *Isles Rases*, in latitude 10° 55′ or 11° 0′.

Perhaps the most likely solution is that (like Narcondam, as previonsly mentioned) Barren Island was duplicated on the charts, through discrepant determinations of its position. But it is at least a possibility that, like Graham's Island, in the Mediterranean, the southern Isle may have been an ephemeral one, due to a volcanic eruption, chiefly of fragmentary ejecta. It is conceivable that, after it had been washed away by the sea, the last visible remnants were the rocks reported by Captain Sharrington, 5 or 6 leagues S. S. E. of Barren Island, and that even these subsequently disappeared, thus explaining Horsburgh's remark that Sharrington's account "is rendered doubtful, for no signs of a shoal-bank in the situation described have been discoverd for many years."[2]

Another possibility is that the temporary Island, and Sharrington's rocks, were S. S. W. of Barren Island (the S. S. E bearing given by Taylor being due to a not uncommon kind of clerical error). This would place them in the line joining Flat Rock, Barren Island, and Narcondam, and on the suppositional submarine ridge of Dr. Frain,[3] and would account, in another way to that suggested above, for the rocks not being re-discovered to the S. S. E., as well as for the statement of the Portuguese Captain. It would be useless, however, to pursue this speculation reared on such a slender basis.

Blair, 1789.

I have made unsuccessful attempts, at the libraries mentioned, to discover the original of Captain Blair's report on the Andamans, part of which, relating to Barren Island, is quoted by Lieutenant Colebrooke in the Asiatic Researches. The following letter,[4] however, dated 19th April 1789, serves to supplement the above: "To the Right Hon'ble Charles Earl Cornwallis, K. G., Governor General, etc., in Council:—

My Lord * * * * After examining Diligent Strait and the archipelago, I proceeded to Barren Island and found the volcano in a violent state of eruption, throwing out showers of red hot stones and immense volumes of smoke. There were two or three eruptions while I was close to the foot of the cone; several of the stones rolled down and bounded a good way past the foot of it. After a diligent search I could find nothing of sulphur or anything that answered the description of lava. * * * I have, &c. "Archibald Blair."

[1] The 'Flat Rock awash' of the Admiralty chart; that reported by Captain Justice.

[2] India Directory, 3rd edition, 1827, Vol. II, p. 37.

[3] See abstract of his memoir in the following bibliography.

[4] Bengal Political and Secret Consultations. Dated Fort William, the 21st August, 1789. India Office Records. The portions of the letter omitted relate to the Andaman Islands.

The preceding account is, in most respects, very similar to that in the report alluded to, and the chief interest lies in the final sentence. I have argued, on other grounds,[1] that the lava streams which now extend from the central cone westward towards the sea were emitted after Blair's visit; but his own statement, that after diligent search he could find nothing resembling lava, puts the question beyond discussion. It is scarcely conceivable that any one, however inexperienced in volcanic geology, could fail to recognize the true character of such typical streams at the first glance.[2] There are, however, still further proofs that the lava was emitted after Blair's time. From the points of issue the streams flowed down the slope of the cone, and their heads now constitute a portion of its surface, so that there have been no accretions to the cone since the occurrence in question. But it is shown, in the succeeding paragraphs, that the cone has greatly increased in bulk since 1789, and any lava emitted then, or previously, and solidified on its flanks, would now be deeply buried beneath the later products of eruption. I have previously stated,[3] that no fragmentary ejecta (scoriæ, &c.) have ever fallen, direct from the crater, on to the surface of the lava, which must, therefore, have been emitted after the last eruption of such material. In other words, the lava must be the latest volcanic product, and cannot, apparently, have been emitted earlier than 1804, the date of the last outburst of which we have any record. We have no reason to suppose that the different streams were emitted at considerable intervals, and the existence of the hot spring in 1832 shows that the southern stream, at least, had been poured forth before that date.[4] That Blair found no sulphur is very natural. The superficial deposits are entirely confined to the newer cone,[5] which was inaccessible to him, owing to the eruption. Even if he could have ascended it, he would have found none. The present deposits have been formed since the last eruption of scoriae, and therefore long after his visit, while the outburst he witnessed must have destroyed, or buried, any previously visible.

Captain Blair's landing on the island still remains the first, of which we have any record.

It is worthy of mention in connection with Blair's visit, that Test's "view of the volcano on Barren Island, bearing east, about one mile off" [6] taken the day before Blair landed, gives the means of arriving at an approximation to the height of the newer cone at that time. The sketch represents the summit of the cone as rising very slightly above the sky line of the old crater rim behind it, and a careful comparison of corresponding points in the sketch, and in Hobday's map of 1884, shows that the artist, the summit of the cone, and the eminence on the old crater rim which Hobday marked as 1060 feet, in height, were in a line; and likewise shows that the eminence in question was concealed, and only just concealed, by the summit of the

[1] Mem. G. S. I., Vol. XXI, p. 271.

[2] There was of course lava in abundance visible to Capt. Blair, at a distance, where it outcrops, interbedded with scoriae, on the scarped walls of the ancient crater. But its petrological character in such position would be far from self-evident to a non-geologist.

[3] Mem. G. S. I., Vol. XXI, p. 271.

[4] *Ibid* p. 274.

[5] There may possibly exist buried deposits amongst the rocks of both the ancient and the newer cone.

[6] A water colour sketch measuring 16½ inches × 6: British Museum library, Press mark K. 116, 31, *Vide* Mem. G. S. I. Vol. XXI, p. 262, the illustration accompanying this paper is a photographic reproduction on the scale of one-half.

cone[1]: in other words, the eminence and the cone subtended almost exactly the same angle, their respective distances from the point of view, and the height of the eminence,[2] being obtained from the map, give the height of the cone as exactly 800 feet, assuming the two angles involved to be identical, and that Test estimated his distance from the shore correctly. I do not think any probable difference in the angles would make a difference of more than 20 or 30 feet in the height, while an error of a quarter of a mile in the estimated distance, one way or the other, would make a difference of about 30ft. The errors due to these two sources if they exist, may partially, or entirely, neutralize each other; but even if they are both of the same sign, the total error is probably well under 100 ft., and is almost certainly not over this amount. While, therefore, it may be taken as almost beyond question, that the height of the cone was between 700 and 900 ft., it is much more likely that it was between 750 and 850 than outside these limits, and the most probable altitude is about 800[3].

Lieutenant Wales' sketch, as reproduced in the Asiatic Researches (Vol. IV) is on a smaller scale than Test's, and shows marks of less careful elaboration; but the height calculated from it agrees very fairly with the above, giving the most probable elevation as between 800 and 830 ft., the lower figures being the more likely.

Corroborative evidence of a considerable increase in the size of the cone is afforded by a large protuberance, represented in Test's sketch on the lower part of the north-western slope. This was quite obliterated in 1884, owing, doubtless, to its having been buried beneath the ejecta that have been emitted since Test used his brush.

Supposing the true height to have been 800 ft., the cone, which is now 1015 must have just doubled in bulk between the time of Blair's visit and 1857, since which date we know that there has not been any eruption, a suggestive conclusion in regard to the period of time during which the entire pile may have been heaped up.[4]

Test, like others,[5] over-estimated the slope of the newer cone, where, as is mostly the case, the sides are composed of fragmentary ejecta, the declivity is almost perfectly uniform, at an angle of about 32 degrees, except near the base, where the inclination gradually diminishes in a graceful curve.[6]

[1] That is to say if the cone were away, the sky-line of the crater rim would be seen to rise towards, and culminate in the eminence. As the sky line at each side is but slightly lower than the summit of the cone (in the sketch), the eminence must be, as nearly as possible, equally high.

[2] Test's sketch gives no reason to suppose that the height of the eminence is different now to what it was in 1789, although it is perhaps a few feet more, owing to accumulations of scoriae due to the eruptions since then. Any alteration due to movement of the crater walls (had such occurred) would probably be in the direction of subsidence, and would tend to reduce the calculated height of the newer cone.

[3] According to Blair's account, as quoted by Colebrooke, the elevation was "1,800 feet nearly"; a manifest clerical error. Were the figures he actually gave 800?

[4] *Cf.* Mem. G. S. I., Vol. XXI, p. 265.

[5] As pointed out by Dr. Ball (Records, G. S. I., Vol. VI, p. 82).

[6] See illustration in Mem. G. S. I., Vol. XXI, p. 251.

The following extract from the log of the Ship 'Worcester,'[1] commanded by Captain Hall, adds one more to the recorded eruptions towards the close of the last century:—

Hall, 1795.

"Sunday, 20th December, 1795. At 10 A.M. the Commodore made the signal for seeing the land. Saw a long Island higher at the westward end sloping gently to the eastward N. W. ½ W. 14 or 15 leagues off deck. At noon it bore from N. W. to N. W. ½ W. take it for Barren or Monday Island. In the centre a smoke arises and has the appearance of a volcano. Its Lat. by the bearings is 12° 22′ N. and Long. by my chron. No. 1, 93° 54′ E. Greenwich × × × ×.

"Monday, 21st × × × ×. At 6 A.M. it bore S. ½ W. about 10 leagues and Narcondam (both from the deck) N. N. E. ¾ E. about 12 leagues. It was astonishing the repeated columns of black smoke which were sent up. There appeared no hill (as the whole Island is nearly a plain surface gently sloping to the eastward as mentioned in yesterday's log) but the smoke was from the other side of the ridge or on the eastern side."

Any one unacquainted with the true topography of the Island, and viewing it from a distance of several leagues, might easily suppose it to have a nearly plain surface, or to form a ridge. Captain Hall's remark that the Island is "higher at the westward end sloping gently to the eastward" agrees with Captain Taylor's that "the westernmost extremity is the highest, and makes with a peak descending to a low point to the eastward." But this appearance is evidently a deceptive one, as Captain Hobday's map shows that the volcano is highest towards the south-east, and we have evidence, in Test's sketch of the Island in 1789,[2] that, as far as the ancient cone is concerned, the outlines then were practically identical with the present ones.

The volcano was again in eruption at the end of January 1804, when H. M. S. "Caroline" passed the Island. The log[3] contains the following entry on the 31st—"Several eruptions of fire from the volcano on Barren Island during the night." This outburst (as pointed out by Dr. V. Ball[4]) is also mentioned, by one of the officers, in an "account of a voyage to India and China, etc., in H. M. S. "Caroline."[5] His remarks are given in the following table.

Cason, 1804.

Not one of the observers before Colebrooke (1787) record any appearance of smoke rising from the Island, or make any remark indicative of their being aware of its volcanic nature, from which it may not unreasonably be assumed that, when they saw the volcano, it was quiescent or at most giving off a little steam.[6] It seems difficult to imagine that while the bearings, etc., of the Island were duly recorded in the log, an eruption, if witnessed, should be absolutely ignored, and we may, perhaps, further surmise that the volcano was in the same condition when seen by the unknown

Probable condition of volcano in 18th century.

[1] India Office Records.

[2] *Vide* accompanying reproduction and Mem. G. S. I., Vol. XXI, p. 262.

[3] Public Record Office.

[4] Geological Magazine, 1888, p. 404.

[5] Phillip's Voyages and Travels, Vol. V.

[6] Colebrooke saw smoke when he was 7 leagues off the Island, and Hall (1795) when 10 leagues, or more. Such indeed would be easily visible when the Island itself was below the horizon.

observers who first applied the names 'Monday' and 'Barren' Island; at dates we are unacquainted with, but which seem not improbably to lie between 1708, when Stretham charted the Island as an anonymous one, and 1748, before which time both names appear to have been in use.[1] Had the volcano been in eruption when the observers in question saw it, it does not seem unlikely that they would have given names suggested by the remarkable phenomenon of which they were spectators.[2]

Assuming, however, that the volcano was quiescent at the dates previously given, it would still be unsafe to argue very confidently as to its general condition in the eighteenth century, as, during the intervals of which nothing is known, many eruptions may have occurred for ought we can assert to the contrary. But, at the same time, the fact that on every one of the six dates included in the following records, between 1787 and 1804, the volcano was very active, and mostly in eruption, while on each of the (three or) four dates between 1748 and 1780 it appears to have been quiescent, can hardly be attributed entirely to chance. Hence it can scarcely be doubted that several outbursts during the two decades following 1785, have passed unnoticed, while we shall, perhaps, not greatly err if we regard the preceding four decades as a period of at least comparative, and possibly total, tranquillity. There is also, as we have seen, some very slight ground for surmising that this tranquillity may have extended back to the early part of the century. Of antecedent ages we know nothing from direct observation unless the suggestion thrown out in connection with Linschoten's map may be taken as one very faint hint.

Tabular abstract.

In conclusion, it may be convenient to add a revised edition of the tabular abstracts given in my memoir on the volcano,[3] incorporating the preceding records, and also the observations that have been made since 1884.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
1595 .	The Island appears to have been known at this time, but there is no indication of its volcanic nature having been recognised.	......	Maps in Van Linschoten's itinerario.
7th Dec. 1708.	Dormant	......	Captain Gough; log of ship "Stretham."
28th & 29th Oct. 1748 .	Dormant	......	Captain Cheyne; log of ship "Lapwing."
1758 .	Dormant ?	......	Captain Mills, of ship "Drake." "Memoir of a chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[1] *Cf.* Notice of Cheyne's observations, and foot-note mentioning "Le Neptune Oriental" etc.

[2] *Cf.*, however, foot-note in the next paper, on the possible origin of the name 'Barren.'

[3] Mem. G. S. I., Vol. XXI, p. 272 and 275.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
2nd Nov. 1771 .	Dormant	......	Captain Justice, of ship 'Union' M. S. Bengal Public consultations, and Memoir of a chart of the Indian Ocean (op. cit.), p. 36.
13th & 15th Jan. 1780 .	Dormant	......	Captain Taylor, of ship "Ceres," Dalrymple's Nautical Memoirs, Vol. II.
12th May 1787 .	"Column of smoke ascending from the summit" was seen from a distance of 7 leagues. No nearer approach to the Island was made.	......	Lieutenant Colebroke, Asiatic Researches, Vol. IV. p. 397.
24th March, 1789.	"The volcano was in a violent state of eruption, bursting out immense volumes of smoke, and frequently showers of red hot stones. Some were of a size to weigh three or four tons, and had been thrown some hundred yards past the foot of the cone. There were two or three eruptions, while we were close to it; several of the red hot stones rolled down the sides of the cone, and bounded a considerable way beyond us." The newer cone was probably about 800ft. high.	No mention of the spring. Blair was the first who landed on the island, as far as is known.	Capt. Blair, quoted by Colebrooke; *loc. cit.* Letter from Capt. Blair, dated 19th April, 1789. Test's sketch of 23rd March, 1789.
1791 .	"A quantity of very white smoke close to the crater."	......	India Directory, by J. Horsburgh, 3rd edit. (1827), Vol. II, p. 37.
20th and 21st Dec., 1795.	On 20th smoke observed: on 21st, "It was astonishing the repeated columns of black smoke which were sent up."	......	Capt. Hall; log of ship "Worcester."
November, 1803.	"Exploded regularly every 10 minutes, projecting each time a column of black smoke perpendicularly to a great height; and in the night, a fire of considerable size continued to burn on the east side of the crater."	......	Horsburgh; *loc. cit.*
29th—31st Jan., 1804.	29th. Volcano "was burning very fiercely, the eruptions taking place every eight or ten minutes, with a hollow rumbling noise. * * * We passed within a mile of it, and as the winds were trifling we observed the eruptions for three days and nights successively." 31st. Several eruptions of fire during the night. The recent lava streams appear to have been emitted not earlier than this date.	......	Officer of H. M. S. "Caroline"; Phillip's Voyages and Travels, Vol. V. Log of the "Caroline."

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
March, 1832 .	"Large volumes of thin white smoke kept continually issuing" from the summit. The southern lava stream was emitted before this date, as evidenced by the existence of the hot spring. Probably the other recent streams had also been poured forth.	"On approaching to within a hundred yards of the shore, we were suddenly assailed by hot puffs of wind, and on dipping our fingers into the water, were surprised to find it as hot almost as if it had been boiling. The stones on shore, and the rocks exposed by the ebbing of the tide, were smoking and hissing, and the water was bubbling all round them."	Commander of a ship; Journal, Asiatic Society of Bengal. Vol. I, p. 129.
April, 1843 .	From the summit of the cone "a clear and full stream of transparent vapour issued, so transparent that it was not perceptible from the sea."	...	Captain Miller; Calcutta Journal of Natural History, Vol. III, p. 423.
1852 .	Very active. . . .	...	"Bombay Times," July, 1852.
18th Dec., 1857 .	"Some smoke was seen occasionally to issue from the slope of the cone" a little way below the summit. The date of the last eruption is unknown, but the unchanged condition of the crater shows that there was none between December 1857 and April 1891.	Temperature "too high to be borne by the hand, the mercury in the only thermometer in our possession rising immediately to 140°—its limit."	Dr Playfair, Selec. Rec Govt of India (Home Department), No XXV, p. 123. Mem. G. S. I., Vol. XXI, p. 268 Dr. Prain; see below.
Ibid. .	...	"A natural boiling spring."	Dr. Mouat; Researches amongst the Andaman Islanders.
19th March, 1858	"Clouds of hot watery vapour," with a sulphurous smell, issued from cracks near the summit, on the northern and southern edges of the crater. The recent lava streams were (superficially) "cold."	"The water, where escaping from the rock, must have been nearly at the boiling point"	Dr. Liebig; Zeitschrift der Deutsch Geol. Gesellschaft, Vol. X, p. [illegible]. Selec. Rec. Govt of India, No. XXV p. 126. Also in Jour. As. Soc. Bengal, Vol. XXIX, p. 1; and in Mouat's Researches.
1862 .	Sulphurous vapours issuing along the edge of the crater.	"Scalding hot" . .	Rev. C. Parish; Proceedings, Roy. Geog. Soc., Vol. VI, p. 217.
19th April 1866	A whitish vapour was evolved from several deep fissures near the summit.	158° to 163° F. . . .	Andaman Committee; Proceedings, As. Soc. Bengal, Oct. 1866, p. 215.
March 1873 .	From the highest point on the northern edge of the crater a thin column of white vapour, and sulphurous fumes were slowly poured forth.	130	Prof. V. Ball; Records, G. S. I., Vol. VI, p. 88.

Date.	Condition of volcano.	Temperature of hot springs	Authority.
Feb. 1884 .	Superheated steam, with sulphurous vapour issued rather copiously from the solfatara on the north side of the crater, the column, as it rose into the air, being visible from the landing-place, or even some distance out at sea. Steam, in smaller quantity, issued from some other spots also.	106° to 116° . . .	F. R. Mallet; Mem. G. S. I., Vol. XXI, p. 273, 274.
28th April 1886 .	"From the ship the thin column of steam (from the central cone) could be barely seen at 3 miles distance."	110°	Capt. Carpenter, R. N., H. M. I. M.S. 'Investigator'; Records, G. S. I., Vol. XX, p. 48 Mr. Daley, of Investigator; Ex. Cit.
April 1891 .	Some steam issued from the crater but considerably less than in 1886; it was not visible from the sea, or even from the landing-place. New crusts of sulphur, from ½ to 2½ inches thick, had been formed at the solfataras since February 1884.	102° to 106°. . . .	Dr. Prain; Proceedings, As. Soc., Bengal, May, 1891, p. 84.
1894 .	"The Volcano is apparently entering on a period of renewed activity." This somewhat vague statement does not seem to have been corroborated	......	Port Blair correspondent of the Allahabad 'Pioneer', quoted in 'Nature', 7th June 1894, p. 131.

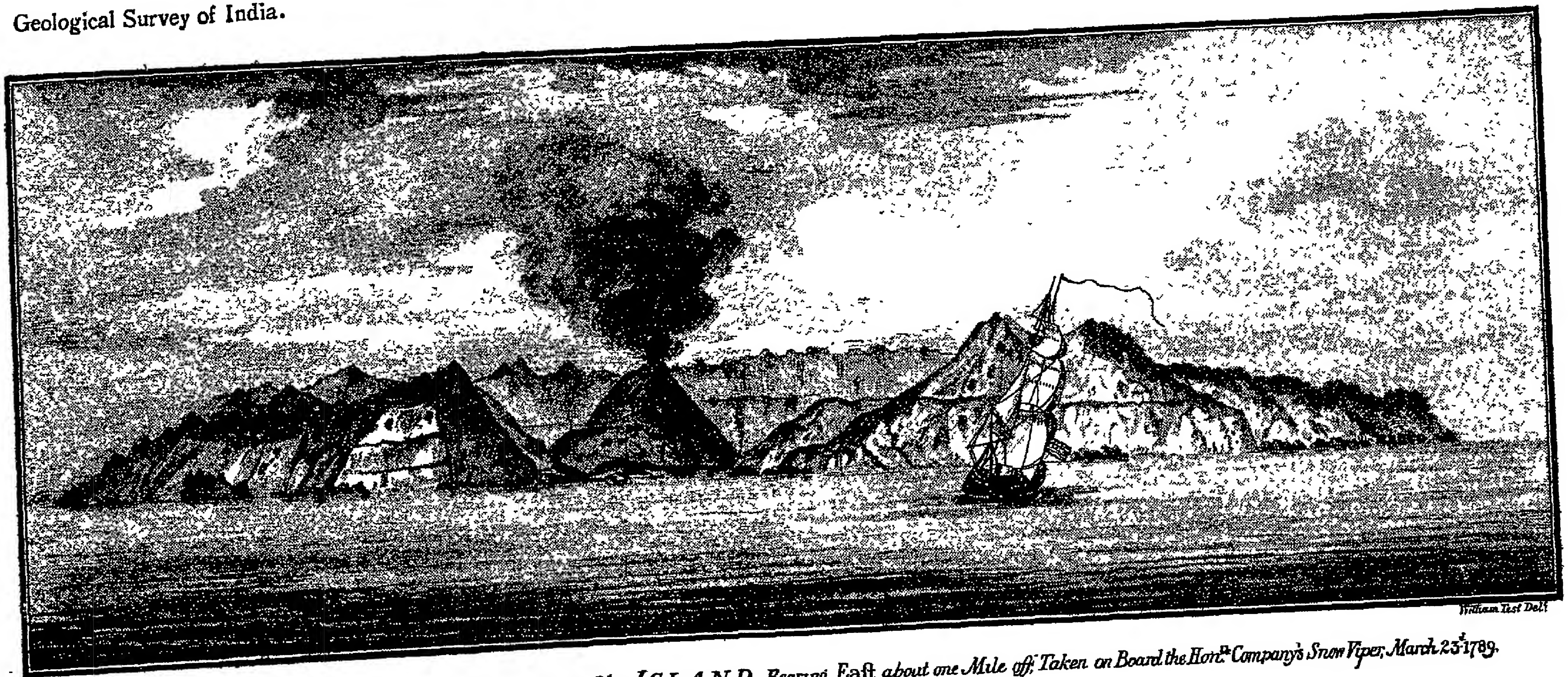
Bibliography *of* Barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks by* F. R. MALLET, F.G.S., *late Superintendent, Geological Survey of India.*

The Bibliography of the Islands up to 1884 may be gathered from Dr. V. Ball's paper in an earlier volume of the records,[1] from my report of 1884, and from the preceding pages. The following papers have appeared during the last ten years, but I am not prepared to say that the list is complete, as there may be other references to the Islands which have escaped my notice.

1. "Volcano of Barren Island in the Bay of Bengal": American Journal of Science, Vol. XXXI (1886), p. 394. A critical notice of my Memoir, by Professor J. D. Dana.[2]

[1] Vol. VI (1873), p. 81. Republished in the Geological Magazine 1879, p. 16.

[2] It is, perhaps, worth mentioning here, that the statement, alluded to by Prof. Dana,



A VIEW of the VOLCANO on BARREN ISLAND, Bearing East about one Mile off; Taken on Board the Honble Company's Snow Viper, March 23d 1789.

The writer discusses the way in which the upper part of the cone of a volcano is destroyed, and a great crater, like the ancient one of Barren Island, produced. He holds that, during a paroxysmal eruption, the portion of the cone in question is not blown away peacemeal, but that the walls of the crater are undermined by the melted lava, and sink down in consequence into the abyss beneath. "Finally in the catastrophic eruption when the force from the rising vapours and from other conditions becomes greater than the mountain can withstand—a point often abruptly reached—the sides break and one or more fissures let out the liquid lavas. However explosive the action, the solid rock of the summit of the cone, while it may be more or less removed by the forces engaged, instead of being projected over the outer slopes, sinks down into the abyss so made. Thus a volcanic cone under the most formidable of explosive eruptions may lose its head, but if so, it is by swallowing it, or simply by a collapse. The same is the process in quiet Kilauca, the solid lavas of the borders of the fiery region sink because the discharge of the liquid rock makes a void beneath them."

A subsidence of the lava in Kilauea, and concomitant collapse of the crater walls into the fiery lake, which took place last July, was observed by Mr. L. A. Thurston, apparently the first actual eye-witness of such an occurrence. His graphic account[1] is in complete accordance with Professor Dana's view. But Kilauea is a volcano of an unusual type, and widely different from Vesuvius or Barren Island. However large a share engulphment may have in producing great craters in volcanoes of the latter type, that it is the sole agent and that ejection of the material of the crater wall, in a more or less communicated state (produced mechanically, or by fusion), never plays a prominent part in the affair, is an opinion widely at variance with that held by most volcanologists.

2. "On soundings recently taken off Barren Island and Narcondam by Commander A. Carpenter, R.N., H.M.I.M.S., 'Investigator,' the officer in charge of the Marine Survey of India." By F. R. Mallet. Records, Geological Survey of India, Vol. XX of 1887, p. 46.

The results of soundings, taken in May 1886, are given with some remarks thereon. The depths measured within four miles of Barren Island range up to 855 fathoms, and those within a league of Narcondam up to 652. Sections of the islands are appended, based on Captain Carpenter's soundings and Captain Hobday's maps.

3. "The volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, M.A., F.R.S., F.G.S, Geological Magazine, 1888, p. 404.

Mainly a notice of the chief results of the survey by Captain Hobday and myself in 1884, with some remarks thereon. Refers to the eruption of January 1804, seen by an officer of H. M. S. 'Caroline' (*vide* preceding paper.)

4. "The Andamans and Andamanese." By Colonel T. Cadell, V. C., Scottish Geographical Magazine, February 1889, p. 56.

Includes a brief account of Barren Island, written partly from personal observation, partly from previous descriptions.

that the cone "has been entirely built up during the last 1800 years," is not merely in connection with Barren Island, but a quotation from Professor Judds' 'Volcanoes,' in reference to Vesuvius.

[1] American Journal of Science, Vol. XLVIII (1894), p. 338.

5. "On the present condition of Barren Island." By D. Prain, M.B., Proceedings, Asiatic Society of Bengal, May, 1891, p. 84.

Gives some of the geological results of a visit in April 1891—An abstract of these is included in the preceding table.

6. "Remarks on the Fauna of Narcondam and Barren Island." By D. Prain, M. B., Proceedings, Asiatic Society of Bengal, April, 1892, p. 109.

The paper is almost entirely geological, but, at the end, contains some remarks on the relation between the geology and biology. The author recognises that the islands are, and always have been, oceanic. "The present physical conditions in Narcondam appear, moreover, to be very ancient; there is no trace of a crater at the top of its peak which rises 2,330 feet above the level of the Andaman Sea, and the whole island is clad with a dense jungle much richer in species than the forest on Barren Island is. But though the present biological features of Barren Island are of a much more modern aspect, it is not necessary to consider that island as really less ancient than Narcondam. The topography of its outer cone, combined with the historical fact of recent activity on the part of the volcano, points to the possibility of some catastrophe similar to that which devastated Krakatau, having once happened in Barren Island, and if this has been the case it would follow that the island must have required, even if previously covered with vegetation, to be stocked *de novo* with vegetable and animal life. Still, granting that the present fauna and flora of Barren Island are of more recent introduction than those of Narcondam, the fact remains that we must look upon every species present, even in the island with the older biological features, as an immigrant one."

The only catastrophic outburst of which evidence still remains, and that, I presume, referred to by Dr. Prain is the one which probably effected the truncation of the ancient cone, and originated the crater now over a mile in diameter. From a biological point of view, as well as from a geological one, therefore, the period at which this change took place is of some interest. It is impossible to form any definite estimate of the time involved, but there is reason to believe that the event occurred at a very remote epoch. The deep gorges which score the external slopes of the volcano, point to long-continued denudation, which shows no apparent signs of having been interfered with by lava flows from the ancient cone. But still more suggestive is the gorge which debouches into the crater S. S. E. from the hot spring, unless, as is conceivable, this ravine, drained into a great east and west "barranco," which may possibly have existed prior to the origination of the present amphitheatre, the ravine must, apparently, have been excavated since the amphitheatre was formed. That is to say, since the event in question, some hundreds of feet of alternating scoriæ and lava beds have been cut through near the mouth of the gorge, where it is deepest. The stream, too, which has done the work, owing to its small size, and the porous nature of the rocks, is under the disadvantage of flowing only in the rainy season, and perhaps not constantly even then.[1]

The time indicated above is so immense, compared to that during which the

[1] The water, for some distance seaward from the breach, appears to have been somewhat reduced in depth, owing, doubtless, to the material swept into the sea from the gorge just mentioned, and from the amphitheatre generally, combined with the submarine portion of the recent lava (cf. sections in Vol. XX, p. 48.)

materials of the present cone may have been piled up,[1] as to suggest that the paroxysmal eruption, supposed to have truncated the ancient cone, was perhaps followed by a long interval of quiescence, before the building up of a newer cone was begun, and several such may have arisen, and been destroyed, before the present one was reared. In comparison with the antiquity of the older cone, the existence of the present one may date from almost yesterday. Or, to put it differently, while the duration of the one must be measured by geological time, it is possible for the other to have originated during an even historically recent period.[2]

Granting that life was extinguished by the catastrophe just alluded to, as suggested by Dr. Prain, the question may be raised whether the present fauna and flora date from that epoch, or from a still later destruction due to some overwhelming shower of ejecta. I am not competent to express any opinion as to the time required to re-stock the island: but looking simply to the probable intensity of the eruptions in comparatively recent times, *i.e.*, since the present cone was commenced, I see no cogent ground for regarding a total destruction of the island life as very probable. There is no reason for assuming that the earlier outbursts from the present cone were on an essentially grander scale than the later ones; and I have shown in the preceding paper that a large fraction, perhaps half the bulk, of the cone[3] has been added by the eruptions that have occurred since 1789. But Test's sketch shows that the exterior slopes of the island were well-wooded at that date, and that the arboreal vegetation was not subsequently destroyed may be inferred from Capt. Miller's describing the outer slopes as well-wooded in 1843, and from the fact that no remains of lifeless forest have ever been noticed.[4] At the same time it can scarcely be doubted that considerable damage has been done to the vegetation, perhaps on many occasions. But such damage would be much more severe in the amphitheatre than on the external declivities.[5]

7. "Note on the occurrence of quartz in an Indian basic volcanic rock." By T. H. Holland, A. R. C. S., Bulletin of the Microscopical Society of Calcutta, Vol. II, No. 6 (1893), p. 3.

The rock in question is from Narcondam, and described by the author as a basaltic andesite, the quartz being regarded as of volcanic, not extraneous origin.

[1] Cf. remarks in preceding paper in connection with Blain's visit, and Mem. G. S. I., Vol. XXI, p. 265.

[2] If we may regard the relative bulks of the two cones as giving some sort of rude illustration of the orders of magnitude of the two periods involved, we find that while the newer cone is about 1,000 ft. in altitude, the ancient one was probably once 8,000 or 10,000 from the sea floor (Vol. XX, p. 46), requiring, perhaps, 500 or 1,000 times as much material.

[3] That is to say, the cone above sea-level, and not including the mass of material which was doubtless required to fill up the ancient crater to that level.

[4] *Cf.* Memoirs, G. S. I., Vol. XXI, p. 262.

[5] If the view expressed in the above paragraph be correct, the island can scarcely have acquired its name from any striking barrenness of the now well-wooded outer slopes. Although I believe the name was most probably given on account of the barrenness of the newer cone, and parts of the amphitheatre, it has occurred to me, as a possibility, that, as the word Narcondam is of eastern origin, so 'Barren' may be an English corruption of some name applied by the Asiatic sailors of the region in question. The Hindustani *barna*, to burn, *barat*, burning, and *barhm jon*, a volcano, for instance, are somewhat suggestive. Some reference to the island may yet be discovered which will elucidate the origin of the name.

8. "On the Volcanoes and Hot Springs of India, and the Folklore connected therewith." By V. Ball, C.B., LL.D., F.R.S. Proceedings of the Royal Irish Academy, 1893, p. 151.

Refers, *inter alia,* to Barren Island and Narcondam.

9. "The Volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, C.B., LL.D., F.R.S., Geological Magazine, 1893, p. 289.

Descriptive of a model of Barren Island, constructed under the author's superintendence, and based chiefly on the data supplied by Capt. Hobday's map. A bird's eye photographic view of the model is given, in which the sea surrounding the island is also represented. The paper concludes with some notes on the fauna of the islands.

10. "On the flora of Narcondam and Barren Island." By D. Prain, M.B. Journal of the Asiatic Society of Bengal, Vol. LXII (1893), Part II, p. 39.

A memoir divided into three sections. The first, or 'Introductory sketch,' commences with some remarks on the hydrography of the Bay of Bengal (in its wider sense), for the portion of which, enclosed by the Andaman and Nicobar Islands, Alcock's name of 'Andaman Sea' is adopted. Carpenter's soundings round the two volcanoes[1] are reproduced, with some additions: the configuration of each island is described, and a summary account of its vegetation given,[2] the soundings round flat rock[3] are added, which the author very plausibly suggests is probably of Volcanic origin. The bathymetry of the Andaman Sea is reviewed, and the question of the northern prolongation of the line of volcanoes through the Sunda Islands, Java, Sumatra, Barren Island, and Narcondam is discussed. This the author, following Dr. W. T. Blanford, considers, is to be found in the extinct volcano of Puppa, in Upper Burma, and that near Momein, in Yunnan, which, as he remarks, lie in common with the volcanoes of the Andaman Sea, to the eastward of, and rudely parallel to, the line of elevation represented by the Andaman Islands and the Arrakan Yoma. Evidence is likewise adduced to show that Flat Rock, Barren Island, and Narcondam are not isolated peaks rising from the sea-floor, but are situated along a submarine ridge.

The second portion of the Memoir is an annotated list of the plants found on the islands, and the third discusses the "Nature and origin of the Flora." 174 species were discovered, of which 138 occur on Narcondam and 88 on Barren Island, only 52 being common to both volcanoes. In conclusion the probable mode of introduction—by the sea, by winds, by birds, or by man—is taken into consideration. Appended are two bathymetric charts of the area surrounding the Andaman Islands.

An abstract of the Memoir was given in the Geographical Journal for March 1894, p. 234.

[1] Records, G. S. I., Vol XX, p. 46,

[2] With reference to the foot-notes in Dr. Prain's Memoir, at pages 45, 49, 56, and 77, in connection with the occurrence of cocoanut trees on the islands, I may say that Mr. Wight, 2nd Officer of the I. M. S. 'Celerity,' and I, landed at Coco Bay in Narcondam, and saw the trees in question there. We found a large log of teak, with hewn ends, on the beach, which may be presumed to have drifted from the mouth of some Burman river; a suggestive fact with reference to the origin of the cocoanuts from which the trees have sprung, and of other species of plants also. We, and several other members of the expedition, also landed at Anchorage Bay, in Barren Island, the surf at the time being comparatively slight.

[3] The rock east of Duncan's passage, alluded to more than once in the preceding paper.

DONATIONS TO THE MUSEUM.

FROM 1ST NOVEMBER 1894 TO 31ST JANUARY 1895.

Seven specimens of ozokerite, from Boryslaw, Galicia; 1 of slickenside in conglomerate (magura sandstein), from Czarnoozeki near Krosno, Galicia; 1 of Oil-bearing sandstone, from old shaft, Ober Hieroglyphen, Schiefer, Bobrka Oil-field near Krosno, Galicia; 1 of Diorite with iron pyrites, from Bussein bridge, between Somirx and Dissentis, Vorder Rhine; 1 Faceted pebble from the Boulder Bed of Mount Chel Salt Range, Punjab; 2 Striated pebbles from Ramsay's "Glacial breccia," Abberley; 3 Limestone pebbles, pitted, crushed and scratched by earth movements, from the Nagel fluh of the Molasse, St. Gallen, Switzerland; 3 quartzite pebbles facetted by natural sand blast, Copitz, near Dresden.

PRESENTED BY R. D. OLDHAM, A.R.S.M., F.G.S.,
SUPERINTENDENT, GEOLOGICAL SURVEY OF INDIA.

Octahedral crystals of magnetite, from Shamsunderpúr, Bankúra District.

PRESENTED BY N. BELLETTY.

Specimens of mica from the Dhatu Mines, Pananoa hill, 5 miles S. W. of Nawadih, E. I. R.

PRESENTED BY J. D. JONES.

ADDITIONS TO THE LIBRARY.

FROM 1ST OCTOBER TO 31ST DECEMBER

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BRONN, *Dr. H. G.*—Klassen und Ordnungen des Thier-Reichs. Band II, Abth. 3, lief. 17-18; and IV, lief. 36-37. 8° Leipzig, 1894.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA,

Part 3.] 1895. August.

On the Jadeite *and other rocks, from* Tammaw *in Upper Burma: by* PROFESSOR MAX BAUER, *Marburg University:* (*translated by* DR. F. NOETLING *and* H. H. HAYDEN).

In the following pages I propose to describe the rocks collected by Dr. Noetling at the jade mines near Tammaw in Upper Burma, and which are now in the collection of the Geological Survey of India. These specimens including the jadeite and the serpentine (the most impoitant) bear all the characteristics of true rocks.

Jadeite.

Jadeite.—The jadeite forms a fine-grained mass, chiefly white, and bearing at first sight a certain resemblance to marble. The size of the grains is not uniform; they are at times so small as to be indistinguishable by the naked eye, while at times they are somewhat larger, in which case they are characterised by an elongated form and distinct cleavage. On account of the smallness of the grains no single individual could be separated, and further information could be obtained only by means of the microscope. I will, however, first describe the general appearance of the jadeite.

General characters.

The colour of all specimens under my observation is a clear snow-white on fresh fracture; this monotonous white is, however, relieved by beautiful emerald-green spots, which represent the really valuable part. of the stone. They are of variable size, being sometimes as large as a lentil or a pea, sometimes attaining a diameter or several centimetres. The colour is in many cases very intense, but in others again quite pale, at times forming a faint film-like covering over larger or smaller portions of the surface. As it approaches the white mass of the rock, the colour changes abruptly, without, however, there being any well-defined boundary between the two. The green colour is due to the presence of a small quantity of chromium, for powder of an intensely green colour gives an unquestionable Cr. reaction before the blowpipe: this, however, is less distinct when paler powder is used, and is entirely absent in the white portions of the rock. In the inner portions, when fresh, the lustre is vitreous, but towards the surface becomes somewhat duller. The fracture is uneven and splintery, while the hardness exceeds that of felspar, but is not so high as that of quartz. The tenacity is not very high; at some places splinters can be easily removed. This character varies, however, in different specimens, and at times even in the same specimen. This I believe to be due to disintegration, and also in part to cataclysmic structure, which, as we shall presently see, is a characteristic feature of the jadeite from Tammaw.

Specific gravity.

Special care was exercised in the determination of the specific gravity owing to the fact that in samples of jadeite from Bhamo, which might perhaps be considered identical with specimens from Tammaw, it was found to be very low. The average specific gravity of the Tammaw jadeite is about 3·3, while Issel gives that of two specimens of green jadeite from Bhamo, as 3·10, which corresponds with the values obtained by Damour. Mallet states that the s.g. of the Tammaw jadeite is 3·24. Six specimens of different degrees of coarseness served for my observations. In all of them the s.g. is high, and averages about 3·3, being sometimes higher, sometimes lower. By means of the hydrostatic balance and the pyknometer the following figures were obtained:—3·338, 3·332, 3·330, 3·329, 3·327, 3·325. No connection could be traced between the specific gravity and the texture of the rock. This variation of the s.g. is probably due to small differences in the chemical composition. It is, however, difficult to explain the wide divergence of the results obtained by Issel, Damour and others, and only by the examination of the s.g., chemical composition and microscopic characters of further material can we hope to solve this difficulty. All this, however, should of course be done for one and the same piece.

Chemical composition.

Dr. Busz has made an analysis of one of the coarse-grained pieces (s.g.=3·332), using as fresh and pure a portion of the rock as could be obtained. The results of his analysis are given under I. He specially notes the absence of chromium and oxides of iron.

	I.	II.	III.	IV.	V.
$Si\,O_2$	58·46	59·27	57·63	58·99	59·45
$Al_2\,O_3$	25·75	25·33	24·10	24·77	24·32
$Fe_2\,O_3$	...	...	...	·32	·36
$Ca\,O$	·63	·62	·62	·14	·22
$Mg\,O$	·34	·48	·48	Traces.	
$Fe\,O$	...	·71	·71	...	...
$Na_2\,O$	13·93	13·82	13·82	14·51	14·42
Loss	1·00	...	...	1·14	1·15
	100·11	100·23	97·36	99·87	99·92

The figures obtained by my analysis (I) very nearly agree with those obtained by Damour from a jadeite from Asia (II). If we adopt the views expressed by E. Cohen (Neues Jahrb. für Min., etc., 1884, Vol. I, p. 47), the jadeite under examination as well as that analysed by Damour would have the following composition:—90·1 per cent. of $Na_2\,O$, $Al_2\,O_3$, 4 $Si\,O_2$, 4·59 per cent. of $Mg\,O$, $Al_2\,O_3$, 4 $Si\,O_2$, 1·28 per cent. of $Ca\,O$, $Si\,O_2$. On the other hand the silicate $Fe\,O$, $Si\,O_2$, which has been found in most other jadeites, is entirely absent, while in that from Asia 1·3 per cent. is present. Column III represents the average of I and II, while IV and V give the figures obtained by Oliver C. Farringdon[1] from an analysis of jadeite from Mogaung.

Microscopic characters.

The microscopic examination shows that the ground-mass is composed of a confused aggregate of irregular prisms, varying in size; their length and breadth being in some cases the same, and nearly equal to 1 mm., but as a rule the prisms are elongated, their length considerably exceeding their breadth. In no case, however, did I observe a breadth

[1] Proceedings of the U. S Nat. Museum, Washington, 1894, Vol. XVII, No. 981, pp. 29—31.

of less than 0·1 mm. The ground-mass of the jadeite is perfectly pure, and without a trace of any accessory mineıal. The prisms are perfectly colourless, except at the boundary between two individuals or along small cracks, where a slight discolouration may be seen, probably due to subsequent infiltration. The green spots always retain their colour even in slices: it is, however, very pale, even in cases in which it was originally intense. In very pale sections no pleochroism is noticeable, but thicker slices are slightly dichroic, the colours ranging from a bluish to a yellowish green. The prisms are at times colourless in places. In the centre of the green spots they are coloured, but as they approach the surrounding white ground mass, they begin to lose their colour, and become partly green and partly white. Hence we see that the green patches in the white ground cannot be due to an aggregation of green mineral grains at certain spots, but we must imagine local inpregnations to have taken place by means of a colouring matter containing chromium in solution. This permeates each spot with such uniformity that it does not appear to have any well-defined form even under the highest powers of the microscope. The green prisms are exactly similar in every respect to the white ones, with the sole exception of their different colour. No pitting of the surface can be noticed, the crystals appearing perfectly smooth: hence their refractive index is not high. Very minute liquid enclosures are locally numerous, occurring at some spots in aggregates of several individuals: more often, however, they are entirely absent. The characteristic cleavage of augite is very frequently extremely well-marked. In cross-sections the two cleavages intersect almost at right angles. The angle, however, depends of course on the direction in which the section has been cut. In none of my observations could I discover any difference in the two prismatic cleavages, which appear to be everywhere equally perfect. Hence, the cleavage of jadeite certainly does not justify us in including it among the triclinic minerals. In addition to prismatic, pinacoidal cleavage also occurs, and still more frequently, a cleavage transverse to the prismatic zone similar to that of diopside and other pyroxenes. The angle between the cleavage in this direction and that parallel to the prism faces is about 90°. I obtained values up to 96°, but this angle depends of course on the direction in which the slice has been cut. These cleavages frequently subdivide the prisms into single segments, having a strong resemblance to cross-sections of the prisms. They differ, however, from the latter in being less regular.

In polarised light, the prisms show very vivid interference colours. On sections with oblique extinction, the angle of extinction is very high, rising to 40°. Numerous longitudinal sections, however, have straight extinction, one direction being parallel to the cleavage and the other normal to it. In convergent polarised light the perfectly transparent crystals give very fine and clear interference figures, while owing to the thinness of the slide the narrow rings, as well as the vivid polarisation colours in parallel light, indicate a strong double refraction. According to the direction in which the section has been cut, these figures show the well-known differences in shape. On longitudinal sections, however, with straight extinction, one or two axes always undergo dispersion, with a wide axial angle, and the plane of the optic axis is parallel to the cleavage and perpendicular to the direction in which the section has been cut. If we include jadeite in the monoclinic system, then these sections are parallel to the axis of symmetry and the axial plane becomes the plane of symmetry. The above optical property is intimately connected with the crystal-

B 2

line form, and corresponds to that of all other monoclinic pyroxenes, which, without exception, show inclined dispersion. This, however, cannot be observed in the case of jadeite, owing to its wide axial angle. If, on the other hand, we place jadeite in the triclinic system, these optical properties will be anomalous. It seems therefore impossible to suppose that the mineral belongs to that system. It is true that in cross-sections, the directions of extinction are frequently not symmetrical to both cleavages. This symmetry, however, is found in the monoclinic system only when the direction in which the slice has been cut is parallel to the axis of symmetry. Otherwise, the direction of extinction forms different angles with the two systems of cleavage, and the difference of the angles depends on the more or less symmetrical position of the cleavage prism with regard to the plane in which the section has been cut. The optical symmetry is therefore no proof of the triclinic character of the mineral; and in our special case has absolutely no weight, inasmuch as cross sections also occur showing optical symmetry. The above refers chiefly to the properties of a single individual of jadeite. These, however, are frequently intergrown, and at times occur as a number of long prisms, forming a divergently radiating group with interpenetration, and producing a perfectly uniform groundmass. The longitudinal axis of the prisms do not point in any one direction more than in another, hence the groundmass consists of an aggregate of completely directionless individuals. In none of the specimens, however, is the original structure entirely unchanged. Frequently it is locally very distinct, but equally frequently it is more or less disturbed, in which case the prisms are no longer straight, but become more or less curved, and not infrequently distorted and broken: the fragments are then pushed out of place and a differently oriented substance squeezed in. The distorted prisms frequently exhibit at their ends a sort of fringing, which like the distortion is the result of mechanical action. The result of this action, however, is not merely bending and distortion, or fracture and fringing at the ends, but it even extends to the total smashing of the entire groundmass, which then no longer consists of elongated prisms, but becomes an "aggregate-polarising" agglomerate of small grains, which are the remains of the crushed prisms. Some of the prisms still remain in the fine-grained aggregate, but they clearly exhibit bending, distortion or some form of deformation. Sometimes it is possible to trace a transition from the fine grains to the complete prisms. In fact, this is one of the finest instances of cataclysmic structure, which can only be explained by means of violent compression of the already formed rock. The structure is of course better developed in some specimens than in others; but wherever it is well-marked, two other phenomena may be observed in those jadeite prisms which have been preserved: these are evidently due to the same causes as the cataclysmic structure. One of these phenomena is an undulating extinction which is apparently attributable to a slight deformation of the jadeite prisms. The other is polysynthetic twinning, so similar to that of plagioclase, that at first glance the twinned jadeite crystals might easily be mistaken for that mineral. The jadeite twins, however, gradually pass into single prisms, and the general properties of the twinned crystals are so exactly similar to those of the single individuals that no doubt of their identity can be entertained. The twin lamellæ are not very broad; in fact, as a rule, they are narrow; they are always numerous, more particularly in the latter case. Twinned prisms are frequently bent throughout and

fringed at the ends. It appears that the twins are most numerous in the portions that have suffered the greatest crushing, and are absent where the effects of pressure are not well marked. We must conclude, therefore, that under favourable conditions crushing and pressure would produce in the jadeite a re-arrangement of the molecules into twins, similar to that observed in calcite. This, however, must have happened only in rare cases, for it had not hitherto been observed. The twinning, plane, which in this case must be looked upon as a fault-plane, is distinctly seen to be a transverse plane, corresponding to that otherwise observed as a twinning-plane in pyroxene.

Serpentine.
General appearance.

2. *Serpentine.*—The groundmass of the serpentine is dense, appearing completely homogeneous, with a very dark, somewhat brownish-green colour, which spreads evenly over the whole surface. Fracture uneven and splintery. Hardness considerable, exceeding that of pure serpentine: apatite is distinctly scratched in some instances.

Microscopic characters.

Under the microscope the cause of this anomaly is at once evident; for the specimen is seen to be an altered olivine-rock, the alteration of which into serpentine is not quite complete, but the process of serpentinization is proceeding in the usual manner along cracks and fissures.

Olivine.

In microscopic sections, the olivine is perfectly colourless and transparent: in thick slices, however, it shows a greenish-yellow tinge. It forms an aggregate of rather coarse grains, which in several instances have a diameter of more than 1 cm. They are always irregularly circular, no indication of crystal faces being traceable. Between the larger grains, which throughout the slide extinguish simultaneously, occur aggregates of very minute, confused and variously oriented grains, which appear to be derived from larger olivine grains. This phenomenon seems to be analogous to the cataclysmic structure of the jadeite, a view which is supported by the fact that the serpentine possesses other properties which are undoubtedly due to mechanical pressure.

Serpentine.

The olivine individuals and also the aggregates formed by the small grains are intersected in the usual manner by strings of serpentine of a greenish-yellow colour, which usually show a distinct and very fine fibrous structure, running in most cases parallel to the walls of the small fissures: in a few cases, however, they are perpendicular to the walls. The rock is therefore a fibrous serpentine, very similar to chrysotile, and closely resembles it in the vividness of its polarisation colours. In microscopic slices these rise to the blue of the 2nd order, but by a combination of several fibres lying one upon the other, fall at times to an iron-grey of the 1st order. In all fibres, the direction of extinction is parallel to the fibres, corresponding to the axis of least elasticity as in the case of chrysotile. The strings intersect each other very irregularly as a rule, but occasionally cross in straight lines at right angles to one another, in which case, when the olivine appears dark in polarised light, a regular mosaic-like structure is produced.

Magnetite and other accessory constituents.

With the exception of numerous small black grains, with metallic lustre, no other minerals but olivine and serpentine can be seen. These black grains having a diameter of 1 mm., are magnetic, and hence are probably magnetite. B. b. they give no titanium reaction. Some of the grains are not magnetic, and in the borax bead give a marked Cr. reaction: they must therefore be chromite or picotite, most probably the former, as they did not appear to be particularly hard. These grains are unquestionably the

source of the Cr. which permeates portions of the jadeite, producing the green patches. In the specimens under observation, however, no mineral can be identified as chromite or picotite; if, however, a larger number of specimens were examined, I have no doubt that sections of both minerals would be found. Under the microscope, the grains of magnetite exhibit very regular octahedral outlines; they are sometimes single, but not infrequently form parallel aggregates of small individuals, which, however, are not true skeleton crystals. The whole of the magnetite is always found among the serpentine fibres, and not a trace can be discovered in the fresh unaltered olivine: it is therefore unquestionably a secondary product of the alteration of the olivine into serpentine. A specimen of the serpentine rock, which had been freed as much as possible from magnetite, gave a s. g. of 2·838. If we take the s. g. of pure serpentine as being that of the pikrolite from Amelose, *viz.*, 2·551, and further if we take the s. g. of pure unaltered olivine as being that of chrysolite from the East, *viz.*, 3·331, we deduce from the s. g. of the serpentine from Tammaw (2·838), the fact that it contains 43·19 per cent. by weight of olivine and 56·81 per cent. of serpentine. The percentage by volume being—

Specific gravity.

Composition.

Olivine	36·79 per cent.
Serpentine	63·21 „ „

These figures are of course not absolutely correct, but give a very fair idea of the composition of the groundmass, and certainly prove that not more than one half of the original olivine has been altered into serpentine. The newer portions of pure serpentine, usually observed in connection with this form of alteration, are not absent in the present case. Strings of pikrolite, in particular, may be seen running through the rock. These veins are of lighter colour than the chief mass of the rock, and are, as a rule, very narrow. Some, however, attain a thickness of nearly 2 cm. Some specimens, the outer surface of which is composed of pikrolite, exhibit the characteristic course, straight, striated appearance, producing the effect of a slickenside; and one of these specimens gives unmistakable evidence of the tremendous crushing and pressure which I have already mentioned. Numerous fissures distorted and bent and sometimes very complicated pass right across the striations, occasionally dying out and being replaced by new ones. They are partly filled with finely fibrous serpentine, resembling chrysotile, the fibres of which are usually normal but sometimes oblique to the walls of the fissure. Occasionally they contain pikrolite, of varying microstructure, of which I shall speak presently. The striæ on the pikrolite are displaced by these fissures, producing step-like markings on the striated surface. Sometimes, in consequence of this displacement, single parts are forcibly bent, and the pikrolite more or less squeezed into the olivine and serpentine. Evidence of the same crushing may also be seen in other specimens of the serpentine. In one case the result is a number of thin lamellæ, while the whole mass is squeezed into an irregularly rounded lenticular form, the rock having a soapy feel. On fresh fracture, the pikrolite has faint fatty lustre, but on the natural surface this lustre is much more marked. The colour is light green, with a distinct greyish or yellowish tinge. Only very rarely is the colour uniform, darker patches usually occurring here and there. The surface of the specimens, and at times even the walls of the inner fissures, are covered with a thin layer of a

Pikrolite.

white substance of lustre varying from mother-of-pearl to fatty. Like the serpentine fibres which intersect the olivine, the pikrolite contains much magnetite in the form of irregular grains, some of which are as large as a pea or even a hazel-nut. I have found no non-magnetic metallic grains, nor could I obtain any Cr. reaction. To the naked eye the pikrolite is perfectly opaque.

In places, the newly formed mineral is coarsely fibrous, the fibres being bent and curved, and the mass having the appearance of metaxite. True chrysotile, recognisable by its peculiar silky appearance and metallic lustre, does not seem to occur in large quantities. The specimens under observation show indications of it, but not its typical development. Under the microscope, the pikrolite is light yellow, almost colourless, and not pleochroic. It can hardly be distinguished from the surrounding Canada balsam, and must therefore have the same refractive index. Brownish patches occur here and there in the colourless groundmass, these are due to infiltration of hydroxide of iron. Their structure is always radial to fibrous, but the fibres are not so fine as those of the pikrolite. Not infrequently, broader fibres occur, forming divergent clusters. Like the single rays and fibres these clusters cross one another confusedly at various angles. Larger grains of magnetite are fairly common, always quite fresh and intimately associated with the rays and fibres, at times completely surrounding them and producing the effect of fluidal structure. The polarisation colours are blues of the second order, and, more often, iron-greys of the first order.

The pikrolite which occurs (in strings and fissures, differs from that just described. This variety is formed in the centre of small radiating fibrous clusters, which in polarized light very distinctly show the black cross: the more nearly they approach to the walls of the fissures, the smaller do these clusters become; and they decrease in size more and more, till at length they disappear, becoming so small that even under the highest power of the microscope ($\times$ 600) they cannot be individualised. In this case, the whole seemingly structureless mass exhibits in polarised light an iron-grey colour, in which may be seen here and there a black cross, due to some larger clusters embedded in the minute ones.

I have already mentioned a white mineral which covers the surface of the plates of pikrolite and fills up the fissures. To judge from its mother-of-pearl lustre and soapy feel one would be inclined to identify it as talc. Under the microscope, however, it is seen to be a confused mass of mineral fibres resembling pik rolite; but whether it is fibrous pikrolite or chrysotile can only be determined by chemical analysis, for which the material at my disposal is not sufficient. It is highly probable that, comparatively speaking, a large proportion of this mineral composes the intermediate layer between the serpentine and the jadeite. Unfortunately, however, I have no specimens of that layer.

Certain other substances accompany the serpentine in small quantities. Grown over the pikrolite are small blackish-brown grains, exactly resembling webskyite as first described by R. Brauns. This mineral was discovered in some serpentines derived from palæopikrite from Hessen, Amelose and Reichenstein in Silesia. In miscroscopic slides, these grains become of a light brown colour and transparent, being scarcely affected by polarised light. Unfortunately there is not sufficient material for a more exhaustive examination, but such characteristics as I have succeeded in observing, agree so well with webskyite that there can be no doubt as

to their identity, and R. Brauns was therefore correct in assigning such a wide distribution to that mineral. In addition to the above mineral, there occur small rounded or string-like and very fine-grained portions of a mineral of yellowish colour, not affected by hydrochlor ic acid. This may possibly be a hornstone quartz, such as is frequently found in serpentine. Carbonates, which are not uncommon in serpentines, are entirely absent, for no trace of effervescence could be observed either with hot or cold HCl.

Albite-hornblende rock.

General appearance.

3. *Albite-hornblende rock.*—The only specimen under my observation is of about the size of the fist, and apparently formed part of a large boulder exhibiting both rolled surfaces and fresh fracture. The rolled surface is brown owing to impregnation by hydroxide of iron, the coloration extending for some distance within the rock, but gradually fading and eventually disappearing. At the first glance, one would be inclined to identify this rock as a saussuritic gabbro, owing to the appearance of the fractured surface. The fine white sugary groundmass contains grains of a brown mineral, which cleaves easily and has a metallic lustre on the cleavage faces. Examination proved, however, that these two component parts are neither saussurite nor diallage, and hence the rock is not a saussurite gabbro, but represents a new type. The beautiful, snow-white groundmass is almost indistinguishable from some saussurites, as, for example, from that of Hamberge near Frankinstein in Silesia. It has the hardness of felspar, and fuses with great difficulty before the blowpipe. The s.g. of two fragments were 2·599 and 2·576, which gave an average of 2·587.

Specific gravity.

Microscopic characters.

Albite.

Under the microscope, the groundmass is seen to be a homogeneous aggregate of very small irregularly rounded grains, varying in size from ·02^{mm} to a fourth or fifth of that size. These grains are almost perfectly pure; enclosures being entirely absent, with the exception, perhaps, of a few small liquid enclosures with moveable bubbles. The grains are perfectly transparent and colourless, and between them occur foreign particles, which, however, are never included in them. The white grains show no cleavage faces, but are crossed in one direction by a series of fine cracks, indicating a perfect cleavage. In some cases numerous fine twin lamellæ of plagioclase occur: these, however, are not very common. The polarisation-colours are very vivid, and the surface of the grains is perfectly smooth and without any pitted appearance. Some grains give the interference figures of biaxial crystals, with a wide axial angle, which, however, cannot be measured. According to the analysis of Mr. Busz, the white groundmass is composed of—

Chemical composition.

	I	II
SiO_2	64·60	68·62
Al_2O_3	19·92	19·56
CaO	traces.	—
MgO		—
K_2O	1·02	—
Na_2O	14·01	11·82
	99·55	100·00

It is therefore unquestionable that this represents an aggregate of albite grains most of which are single individuals. This view is also borne out both by the

chemical and physical properties of the mineral. The composition certainly appears to differ somewhat from that of pure albite given under No. II, but we must remember that the groundmass is not entirely composed of pure albite, but also contains the foreign particles, of which we shall presently speak. The groundmass is slightly affected by HCl., and although albite has been stated to remain unaffected by this acid, it is undoubtedly acted on to a certain extent.

Hornblende.

The brown mineral resembling diallage, scattered through the white groundmass, has been proved to be hornblende. It occurs in single crystals of various sizes, the largest being nearly 4 cm. by 2 cm. This, however, is less than the original size of the crystal which was on the surface of the specimen and has been considerably broken. As a rule, the crystals are smaller, but are always as large as a pea. They are not numerous, being scattered throughout the rock. Their outline is generally irregular, although at times rough crystal faces can be made out. The colour is that of brown hair, but sometimes grey, and the cleavage faces have a metallic lustre, resembling diallage or bronzite. Each crystal is bounded by a green margin, while the surrounding groundmass is also coloured green. In both cases, this coloration is due to numerous microscopic enclosures to which I shall presently refer. In all these hornblende crystals, one of the two very well marked cleavage faces is unusually large, and thus gives the crystal its resemblance to diallage or bronzite. The second cleavage is everywhere equally perfect, and these two meet at an angle of $124^\circ\ 47'$, the characteristic angle of hornblende. This value was obtained by measuring three separate splinters, and in every case the results only differed by a few minutes. On one of those splinters a broad plane was observed truncating the obtuse prism edges; this plane corresponds to the orthopinacoid (100, $\infty \bar{P} \infty$) The hornblende showed no signs of fibrous structure.

Owing to the small amount of material at my disposal, I was unable to make an analysis. The green margin, however, as well as those parts of the albite groundmass which surround the hornblende crystals, gave with borax an unmistakable Cr. reaction; but no Cr. could be detected either in the brown or greyish portions of the hornblende or in the white albite. The micro-chemical examination of the hornblende proved the presence of silica, magnesia, lime, iron, and a little alumina but no alkalies. The average s.g. of the brown splinters was obtained in methylene iodide, and proved to be 3·10, being the average of two separate operations. These figures, as well as the cleavage and the other properties of the mineral, enable us to identify it with hornblende. In the Bunsen flame small splinters are slightly discoloured but do not melt. They melt easily, however, before the blowpipe, fusing to a grey non-magnetic glass. Iron must therefore be present in small quantities. Extinction is straight, parallel to the very distinct cleavage-fissures. Thicker slices exhibit very distinct pleochroism, which, however, entirely disappears in thin sections. The vibrations parallel to the axis of symmetry, and therefore perpendicular to the cleavage cracks, are light brownish-red, while those parallel to the cleavage are light yellow, and those perpendicular to both are light bottle-green. These colours differ but slightly in intensity, while the colour changes from red to green or yellow according to the direction in which the hornblende crystals have been cut. Occasionally, especially at the margin of the crystal, the colour becomes a deep bottle-green or even emerald green: this is

most probably due to infiltration of a foreign substance containing Cr. These greenish patches gradually pass, without well-defined margins, into the differently coloured parts. Cross sections having the characteristic hornblende cleavages intersecting at 124°, extinguish diagonally, while the pleochroism varies from brownish-red to green. On longitudinal sections, the angle of extinction is as much as 19°.

Augite.

In the boundary zone between the hornblende crystals and the albite, a large number of needles of a green mineral occur. These are most numerous along the boundary, and decrease in number on each side of it, thus producing intensely green bands round the hornblende crystals. In the albite aggregate, these needles lie in all directions between the albite grains, but are never enclosed by them. In the hornblende, they not infrequently lie parallel to the cleavage, but more often they are disposed quite at random obliquely to the cleavage fissures. They are always straight, and their length, as a rule, is three or four times their breadth in the broader needles, while in the narrower ones the length is much greater. Their sides generally consist of sharp straight lines; sometimes, however, both edges are slightly curved, thus producing spindle-shaped sections. If the ends are not pointed, they are, as a rule, rough and irregularly indented, but never fringed nor bifurcating. The oblique extinction is important, and rises to as much as 36°. Not infrequently square cross sections may be seen, at times extinguishing parallel to the edges. Cleavage is probably present, but it is not well-defined. Transverse fractures obliquely inclined to the longitudinal axis are common. The characteristics above enumerated enable us to identify this mineral with augite. The colour of the larger prisms is an intense bottle-green to emerald-green, and thus produces the green zone already mentioned as occurring round the hornblende crystals. The narrower needles are of lighter colour, while the narrowest are almost colourless. As a rule, the pleochroism is faint, the colours varying between closely related shades of green. The broadest needles, however, occasionally show a pleochroism ranging through bottle-green and dark greyish-blue to colourless. All are perfectly clear and transparent, and entirely free from inclusions. This mineral is most probably a pyroxene, closely related to diopside or sahlite, which derived its green colour from a small percentage of Cr., and is in fact a chrome diopside. Unfortunately the scarcity of the material precludes a more searching examination of this mineral.

Rhombic pyroxenes and other accessory minerals.

I have already mentioned that a small number of brown crystals may be seen between the albite grains. These show numerous cleavage cracks, parallel to which straight extinction occurs. They consist of oblong plates of about ½mm. in length, the cleavage running parallel to the longer axis. This is most probably a rhombic pyroxene, not very rich in iron, very possibly bronzite.

Lastly, under a moderately high power, a very fine-grained aggregate may be seen, scattered here and there among the grains of albite, and running in fine strings into the hornblende crystals. This is always associated with a large number of the green to colourless augite crystals already described, which are particularly numerous in this aggregate. In thin sections, under a high power, these aggregates are seen to be clusters of minute radial fibrous spherulites, which between crossed nicols show, more or less distinctly, the characteristic black cross. The substance

is colourless and gives very vivid polarisation colours, but cannot be more accurately determined.

From the above description, it is evident that the specimen under consideration is an albite-hornblende rock, in which the albite grains form a dense groundmass, containing porphyritic hornblende crystals. The remaining minerals have no particular share in the composition of the rock, and are therefore merely accessory constituents.

Hornblende-glaucophane schist. General appearance.

4 *Hornblende-glaucophane schist.*—This specimen has a dark brown surface, in some places rough and in others smooth, but apparently not much rolled. It is a schistose rock of an intense emerald to grass-green colour, and bears a strong resemblance to smaragdite. A closer examination, however, at once reveals the fact that it represents an aggregate of greyish hornblende individuals, largely permeated by green enclosures, which impart to it its remarkable colour. The greyish portions pass in places into a deep green, but in other places again the green colouring matter is entirely absent. The hornblende individuals are most irregularly intermixed, and show no signs of definite arrangement. They attain a length of as much as 3, and breadth of as much as 2 cm. They have no definite crystalline outlines, but their cleavage is perfect, the angle between the two prismatic cleavages averaging 124½°. This angle could not, however, be accurately ascertained, owing to the frequent distortion of the prisms, which at times even causes a fringing of the ends. The orthopinacoid was observed on one of these prisms; it gives rather indistinct cleavage, and sharply and straightly truncates the obtuse prism edges. Thin splinters melt in the Bunsen flame; the thicker ones easily fuse before the blowpipe, forming a greenish-grey non-magnetic glass. It is not acted on by HCl., either before or after fusion. The s. g. of the *whole mass*—not that of the pure hornblende—was obtained from two pieces of the rock, the values being 3·113 and 3·126. I endeavoured to obtain the s. g. of the hornblende after removing the green parts, but it was not possible to separate the green colouring matter from the greyish hornblende.

Hornblende.

Chemical composition.

I could, therefore, only ascertain the chemical composition of the whole mass, and not that of the pure hornblende. As we have seen, however, that the whole rock consists chiefly of hornblende, containing only emerald-green crystals, the following figures will represent the chemical composition of the hornblende. Mr. R. Busz, who made analysis I, obtained the following results:—

	I.	II.
SiO_2	53·53	58·76
Al_2O_3, Cr_2O_3	9·10	12·99 (Al_2O_3).
FeO	4·02	5·84
CaO	6·94	2·10
MgO	15·94	4·01
Na_2O., K_2O.	7·96	6·45 (Na_2O).
Loss	2·95	2·54 (H_2O).
	100·44	102·69

In the above analysis the very high percentage of alkali is remarkable: it consists chiefly of Na., containing only a small percentage of K; $Cr_2 O_3$ and $Al_2 O_3$ were not separated. It seems, however, that no small quantity of $Cr_2 O_3$ must be present, for vividly green splinters give an undoubted Cr. reaction in the blowpipe flame. On the other hand, the grey hornblende hardly gives any tinge to the borax. The iron has been calculated as Fe O. According to the above analysis, the mineral proves to be an amphibole, containing a considerable amount of soda, thus resembling glaucophane, which, however, is distinguished by its dark blue colour from the mineral under examination. There are, however, grey varieties of glaucophane. The glaucophane most nearly allied to this mineral is that of Zermatt, the analysis of which is given under II. In both, the percentage of alkali, magnesia and iron very nearly agrees, as also the loss due to ignition. The difference in the percentage of $Al_2 O_3$ is rather more marked, while the difference in the silica is the most pronounced. There are, however, other glaucophanes, which, in this respect, closely resemble the mineral from Burma, *e.g.*, that from New Caledonia contains, according to Liversidge, only 52·79 per cent., while that from Sanjaron in Andalusia contains, according to Barrois and Offret only 47·4 per cent. of $Si O_2$. In the last mentioned variety, also, a low percentage of alumina corresponding to our 8·42 has been observed. From the majority of glaucophanes our mineral differs chiefly in the percentage of lime, for they do not as a rule contain more than 2 or 3 per cent. of CaO. Some, however, are known to contain a larger percentage, *e.g.*, that of Shikoko in Japan, which has a percentage of 4·80, while the glaucophane from Andalusia contains 12·90 per cent.

Glaucophane.

We are therefore undoubtedly entitled to consider this mineral as a glaucophane, inasmuch as its s.g. exactly corresponds with that of most glaucophanes, of which the s.g. ranges from 3·103 to 3·113, the average being 3·12, corresponding to the variety from New Caledonia. The low fusibility is another distinguishing feature. It is a remarkable fact that together with jadeite, which is a pyroxene, there should occur an amphibole, which, owing to its large percentage of Na. closely resembles it in composition. The strong pleochroism peculiar to the dark blue glaucophane is of course less pronounced in the mineral from Burma. In moderately thick slices, however, considerable differences of colour may be seen on rotation of the polariser. The vibrations parallel to $\mathfrak{a}$ are bluish-green, those parallel to $\mathfrak{b}$ greenish-brown and those parallel to $\mathfrak{c}$ yellowish brown, the absorption being $\mathfrak{b} > \mathfrak{a} > \mathfrak{c}$. In thinner slices the same colours appear, being, however, much paler, the differences being therefore less noticeable, while in very thin slices, they almost entirely disappear. The large extinction angle of the Burmese variety contrasts strongly with that of true glaucophane, in which it amounts to only a few degrees, while in the mineral from Tammaw it rises to 28°, a value much higher than that of other rock-forming amphiboles. Under the microscope, cross-sections show the characteristic prismatic cleavage of amphibole. In longitudinal sections the cleavages are very close together, thus producing an appearance of fibrous structure; and, as in the case of the prisms, these fissures are considerably distorted, while the ends are more or less fringed. There can be no doubt that these phenomena are due to the pressure which all the rocks of Tammaw have undergone. In longitudinal sections, also, may be seen an ill-defined transverse cleavage, running obliquely to the

ordinary cleavage fissures. This most probably, as in other amphiboles, represents a cleavage parallel to $\bar{P}\infty$ $(10\bar{1})$, which is a very characteristic feature of glaucophane. Thus we see that the Tammaw mineral differs from true glaucophane only in its abnormal extinction angle.

Augite.

As already mentioned, the hornblende contains numerous fine needles or narrow prisms, which are always elongated in one direction. These are composed of a beautiful emerald-green augite, and produce the fine green colour of the rock, whenever they occur in any quantity. This colour we have already stated to be due to a small percentage of Cr., the very green grains giving a distinct Cr. reaction, while the grey crystals show no such reaction. These enclosures are very similar to those noticed above as forming part of the albite-hornblende rock. The latter, however, do not exhibit such a vivid emerald green, being rather of a bluish-green colour. As in the former case, their lateral boundaries are regular, but their ends are not infrequently fringed or pointed, in which case they assume the spindle-shape already described. The small needles are sometimes arranged very irregularly, but, as a rule, they lie parallel to the vertical axis of the amphibole prisms. The larger non-prismatic crystals form radiating groups, the ends of which are slightly curved and which, owing to their green colour, form a striking contrast to the colourless amphibole. Single crystals become alternately bright and dark in polarised light. The clusters, however, never extinguish entirely, for differently oriented crystals overlap each other. Cross sections show the typical form of augite, but prismatic cleavage is not well marked, the cleavage fissures being somewhat irregular. Transverse fissures, probably representing a transverse cleavage, as in diopside and other pyroxenes, are sometimes seen.

The angle of extinction is fairly high, but it is difficult to obtain measurements of it. Since the larger prisms never extinguish completely, while the smaller crystals are bounded by curves, straight cleavage-fissures being almost entirely absent. In some cases, however, I obtained values up to 50°. The pleochroism is very marked. Cross sections of moderate thickness, however, exhibit only slight differences of colour, the bluish-green remaining almost unchanged during a complete rotation of the polariser. On longitudinal sections, the differences are much more marked, the vibrations in the direction of the axis of elasticity being greenish-yellow, with at times a shade of uranium glass, while those normal to this axis are bluish green as in the cross-sections. Hence during rotation the colour varies between the above tints. Even in very thin slices, this is still visible; the very thinnest needles, however, having no distinct colour, have no pleochroism. The green material occurs in a different manner to that enclosed in the hornblende. The hornblende is frequently intersected by green strings, entirely composed of crystals of augite, as in the previous case. These are, however, of much smaller dimensions, and are, in fact, almost microlites. In rare cases circular clusters of such augite microlites have been observed filling up the fissures and other small cavities in the hornblende, while the larger augites, already described, were unquestionably developed at much the same time as the amphibole, in which they are enclosed; and there is no indication whatever that they were produced by subsequent alteration of the amphibole. It is a remarkable fact that all the Cr. has been taken up by the augite, while none is found in the amphibole.

Geological age.

From the above description of the rocks occurring in the jadeite mines at Tammaw, *viz.*, the jadeite, the olivine-serpentine, the albite-hornblende rock, and the amphibole-glaucophane-schist, we are enabled to form a clear conception of their nature. Noetling believes that the jadeite and the serpentine penetrate the surrounding tertiary sandstone, while with regard to the relations between the occurrence of the two other rocks and the jadeite, nothing is known. Noetling's view necessitates the assumption of an eruption of jadeite and another of olivine rock, following one another; but the petrological composition of these rocks is not favourable to such a view, which would include them among the tertiary eruptive rocks. Judging by the petrological characters, we must consider them as representing a system of crystalline schists.

Now there is no doubt that in former geological times olivine rocks were produced by volcanic eruptions. Nowhere, however, have rocks of this nature been found in beds of such modern date, being according to Noetling not older than of miocene age. Wherever tertiary masses of olivine are known to occur, as for example the enclosures in basalt, they are perfectly fresh, and show no signs of serpentinisation. I wish particularly to emphasize this fact, since the basalt which I shall presently describe, and which occurs in close proximity to the jadeite mines, has no geological connection with the jadeite, but is unquestionably an eruptive rock passing through tertiary strata. In this basalt the serpentinisation of the olivine has just begun, but has not progressed beyond the first stages, while such a complete alteration as that exhibited in the above specimens is characteristic of all ancient olivine rocks—such as palæopikrite—and, as I have already observed, of the crystalline schists.

To consider the jadeite as an eruptive rock would be entirely unjustifiable: for neither in the older nor yet in the more recent series of eruptive rocks has any rock of the nature of jadeite been found. In Turkistan, however, it has been proved to be imbedded with nephrite in the crystalline schists (gneiss and mica schist), and belongs to that series.

The two other rocks also offer material proof in favour of this view, for it is highly probable that the glaucophane-schist is one of the crystalline schists. Hitherto, glaucophane has been found only in gneissic rocks and mica schists, no instance having been recorded of its occurrence in eruptive rocks, much less of its entirely composing such rocks. The same holds good for the albite of the albite-hornblende rock. This mineral frequently occurs as a component part of the crystalline schists, but hardly of eruptive rocks. The peculiar aggregation of the albite grains is in perfect harmony with this view, for such a structure would be by no means remarkable in a crystalline schist. I am therefore of opinion that the jadeite and the other rocks must be looked upon as part of the series of crystalline schists, overlaid by tertiary beds and probably denuded by erosion. It is most probable that they were raised to their present level together with the surrounding tertiary rocks, when these latter were subjected to folding. I have repeatedly laid stress on the fact that these rocks must have been subjected to great pressure, which can only be accounted for by folding. I do not assert for a moment that the above arguments are absolutely convincing, but they certainly support the view which best accords with the petrological evidence, while the stratigraphical conditions observed by Noetling in the mines at Tammaw fully bear out this view. Further observations, however, with regard to the geological conditions of that country, will cer-

tainly decide the question. On the geological map of Burma, west of the Irrawaddi, even west of Mogaung, towards Tammaw, sub-metamorphic rocks are indicated; while crystalline limestones, probably of silurian age, extend to within about two miles of the eastern side of the jadeite mines.

Basalt.

In conclusion, I wish to mention a rock which, although not belonging to the series described from the jadeite mines, has been found on a hill four miles east of Sanka village. It is an excellent felspar-basalt, with blackish-grey fracture, and brown weathered surface. Under the microscope, the felspar—plagioclase—forms a crowd of minute lamellæ, in which only very few individuals are twinned, while a very small number of the crystals are somewhat larger. The felspar crystals form the groundmass in which all the larger constituents of the rock are porphyritically imbedded.

The augite is of a very light yellowish-green colour, without noticeable pleochroism, but with oblique extinction as is usual in basaltic augites. The crystals, which are regularly bounded by straight lines, are usually of considerable size. There are, however, smaller crystals which in their dimensions very nearly approach the lamellar felspars. These small augite crystals form part of the groundmass together with the felspars, but they are not nearly so numerous as the latter. They are much more sharply and regularly bounded than the larger crystals, and probably represent a later generation of augite. As a rule, they are single, but twins are occasionally seen parallel to the orthopinacoid, and not infrequently polysynthetic. Cruciform twins appear to occur, but I cannot state with absolute certainty that any regular intergrowth takes place. The augite, like the felspar, is perfectly fresh, and both are fairly free from foreign enclosures of all sorts. Magnetite, however, generally very regular in shape, is not infrequently included in the augite. Olivine usually forms the largest crystals; it is either perfectly fresh or intersected by a few cracks along which serpentinisation has just set in, only small progress, however, having been made in this direction. It also contains inclusions of magnetite grains. A few dark brown transparent grains of picotite occur, while liquid enclosures containing moveable bubbles are frequently seen, arranged in the well-known zones. Magnetite is fairly common, and usually forms well-defined crystals of considerable size. These crystals sometimes occur singly, and sometimes in larger and regularly-arranged groups. They are partly imbedded in the groundmass between the felspar and augite microlites, and partly occur as enclosures in the larger augites and olivines. As already stated, I consider some of the darker brown and transparent enclosures in the olivine to be picotite. A number of long, colourless needles with straight extinction, and sometimes grouped in clusters, are crystals of apatite. No other minerals have been observed, while glass, in particular, is entirely absent, not a trace of it having been discovered.

The basalt is therefore holo-crystalline and falls under class II of Zirkel's classification, the members of which group are distinguished by a fine-grained, microscopic groundmass, which is crystalline throughout or only contains a small quantity of magma in which larger crystals—in this case augite and olivine—occur. Or if we adopt Rosenbusch's classification, we must describe it as a holo-crystalline porphyritic basalt, in which, notwithstanding the enormous number of plagioclase lamellæ forming the groundmass, no larger plagioclase crystals appear, as is more usually the case. Warm HCl affects the rock but slightly, while cubes of NaCl are not formed after evaporation.

On the Geology of the Tóchi Valley, by F. H. SMITH, A.R.C.S, *Assistant Superintendent, Geological Survey of India* (with pl. 3).

Towards the end of February 1895 I received orders to join the delimitation party at work in the Tóchi valley. A geologist was specially required to ascertain, if possible, whether the reported occurrence of copper and iron in the hills south of the Tóchi river, and between it and the Khaisor, was of economic importance.

Unfortunately, when I received my orders, I was engaged in field-work amongst the southern spurs of the Sulaimán range in Baluchistán, and by the time I caught up the Tóchi column that part of the delimitation work situated in the Tóchi hills had been completed, and I never had an opportunity afterwards of seeing more than the northern or Tóchi flanks of the hills.

Copper and iron.

I may say at once that, as far as I could observe, the hills between the Tóchi and Khaisor rivers contained no minerals of any economic importance. I have not met with any trace of copper, or mineral containing copper during my march along the Tóchi and one or two tributary streams.

The Waziris are said to work and smelt iron ore to a considerable extent in the hills to the south of the Tóchi; and the number of native-made knives seen all over Waziristán shows that there must be a considerable iron industry. The majority of the knives are made of very soft iron, and their value, when sold to Europeans, seemed to be from 2 or 3 rupees each; smaller knives of mottled native steel are fairly common, the price of which seems to run up to anything under 25 or 30 rupees, according to the appearance of the intending purchaser.

The only place where I found any traces of iron ore was Mirán Sháh. There I found several concretions of very pure soft hæmatite, in middle or lower eocene sandstone beds. These beds have *roughly* a north and south strike in this neighbourhood; to the north the series forms the Laram hills, while to the south the hill-country between the Tóchi and the Khaisor, or Khasora, is mainly composed of these same rocks. It is very probable that the iron ore supply is derived from this pure concretionary hæmatite, which could easily be found in sufficient quantities for the manufacture of knives and other small implements, but which would probably run out at once if worked to any great extent. Even if pure hæmatite were found in greater abundance, as is constantly the case in other parts of India, the total absence of fuel would render it useless in this valley.

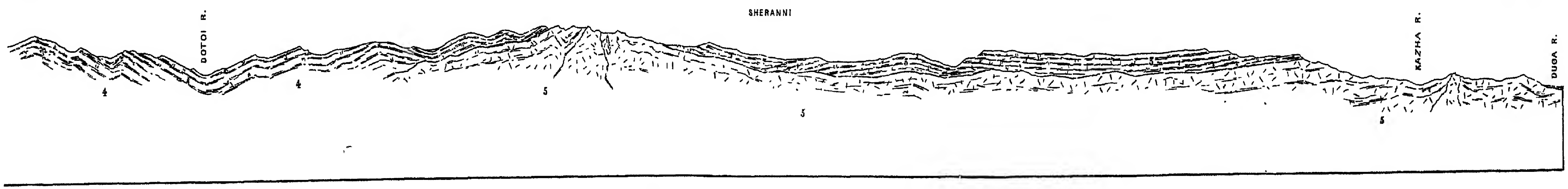
Although my march up the Tóchi was not very successful from an economic point of view, it was none the less interesting geologically, especially as I traversed new country.

Topography.

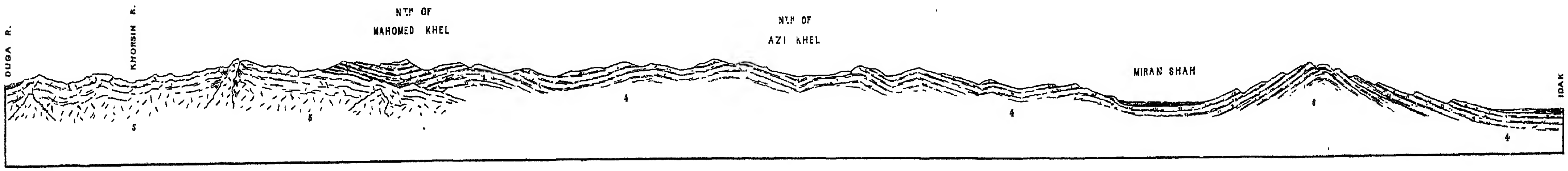
Marching from Bannu up the Tóchi valley, one enters the outer range of tertiary hills near Tóchi village, at a height of about 1,000 feet above sea-level. From here to Dotoi, the farthest point I reached, is about 60 miles in a straight line, and rather more along the river bed which runs almost due east and west. At Dotoi the height is about 5,000 feet, and the higher peaks around run up to 10,000 feet. To the west of the outer hills mentioned above, which run roughly north and south, the river bed traverses two

F. H. Smith.

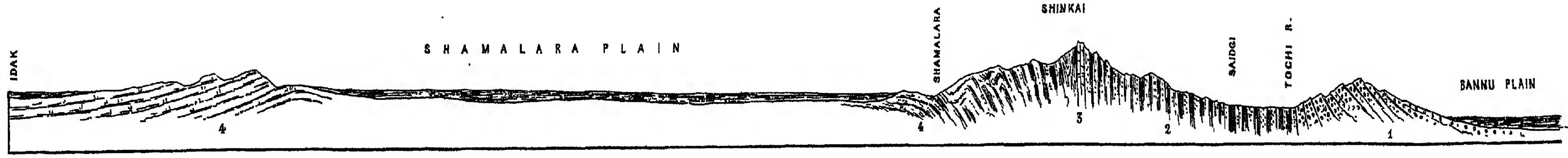
GEOLOGICAL SURVEY OF INDIA.



1. SECTION FROM THE DUGA NALA W.S.W. TO THE DOTOI COUNTRY.



2. SECTION FROM IDAK W. TO DUGA NALA.



3. SECTION FROM IDAK E.S.E. TO BANNU PLAIN.

1. Upper Siwaliks. 2. Lower Siwaliks. 3. Upper Nummulitic limestone. 4. Middle and Lower Nummulitic beds. 5. Tertiary igneous series. 6. Mesozoic (?) Limestone.

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wide plains, the Idar Khél and Idak valleys. Both plains are bounded north and south by hills, which close in to the west of Idak, above which the river-bed lies between irregular hills, forming a more or less narrow valley.

I was able also to march up a tributary of the Tóchi, the Kazha nala, which rises on the Luara plateau under Charkhiaghar to the north of Dotoi, and runs nearly parallel to the Tóchi till it joins it near Pakki Kôt.

Geology.

As the newer rocks present none of the difficulties which are met with in the older rocks which I saw, I will describe the section in descending order. Roughly speaking, the younger rocks are found in the eastern outer ranges, which rise from the Bannu plain, and older rocks appear in the interior to the westward.

The rocks in this outer range—the Shinkai hills—showed a most striking similarity in composition and arrangement to those of the Fort Munro range, south-west of Déra Ghází Khán. This latter range, rising from the Indus plain, presents a perfectly normal section of rocks which dip steeply eastwards under the Indus plain; from upper siwalik conglomerate in the outer ranges, through lower siwalik, upper, middle, and lower eocene rocks, with beds of probably cretaceous age at the base. Having just traversed the Fort Munro range, the similarity between it and the Shinkai range rising from the Bannu plain, some 200 miles to the north, appeared all the more striking to me. Evidently the same, or nearly the same, series of tertiary rocks have been disturbed and folded in the same manner, and for a distance of hundreds of miles along the frontier hills west of the Indus plain. Taking the normal section of the Shinkai range from west to east, nearly the same series of beds is met with.

Siwaliks.

The outermost range commences two or three miles to the west of Tóchi village, where the massive conglomerates and grits of the upper siwaliks dip gently to the east under the Bannu plain. The dip becomes steeper further west, and in the highest ridge of these hills the rocks dip very steeply, still eastwards, till along the bank of the Tóchi river it becomes vertical; this dip is maintained westwards throughout the lower siwaliks and upper nummulitics at least. The thickness of these conglomerates must be great, and is probably several thousand feet, but the lower siwalik beds are of even much greater thickness. In the Saidgi valley the rocks change from conglomerate (east) into an immense thickness of sandstones and shales (west). The conglomerate passes gradually and perfectly conformably into finer sandy strata, which at once become interbedded with beds of shale. The lower siwalik beds consist entirely of grey sandstones and red shales; the latter predominate in the upper beds, but give way lower down to soft sandstone beds, which contain no shale bands at the base. The dip is vertical throughout the whole section of these beds across the Saidgi valley and up to the highest ridge of the hills westward. The strata appear not to be crushed to any extent, but are exposed as a perfectly normal section, with an outcrop of fully 2 miles in breadth, which gives the lower siwalik beds the immense thickness of 10,000 feet. I could find no trace of fossils in either the shales or sandstones.

Upper nummulitic.

Along the ridge of the hills west of Saidgi there runs a bed of white hard limestone, under 200 feet in thickness. The dip is vertical, and at Shinkai in the river bed the exact thickness is 170 feet.

The limestone is full of fossils, the harder bands being almost made up of *nummulites* and *alveolinæ*, while some softer muddy bands are full of gastropods and bivalves, with which I found part of a well preserved crab.

The junction of this white limestone with the overlying grey siwalik sandstone is clearly seen in the river bed. In position they are perfectly conformable; the white limestone is very nodular, so that the upper surface is not quite smooth. The sandstone fills up the irregularities, and the bedding of both is perfectly parallel: the sandstone contains many limestone pebbles for about 2 feet from the junction, but the parallelism appears perfect. The junction of this upper nummulitic limestone with the lower beds is not so well seen, but the white limestone appears to rest conformably on the soft shale beds below. To the north of Sheranni, upper nummulitic rocks occupy a considerable area, forming a flat basin north of the Tóchi. The rocks consist of white limestones and interbedded light green shales; the limestone is identical with that at Shinkai. The thickness of the whole exceeds that of the rocks at Shinkai, but the base beds rest on rocks so much disturbed by igneous intrusions that I could make no very definite observations on the lower beds.

Lower nummulitic.

Below the white limestone comes a thickness of 400 to 500 feet of olive green shales, very like the 'ghazij' shales of the Quetta area, which are of middle nummulitic age; at the base of these I observed some red shale bands, below which come 200 to 300 feet of shales, interbedded with shaly limestone and limestone breccia. The breccia contains many fossil organisms, but I have not found any nummulites amongst them; a fossil fruit was found in the associated shales, but nothing could be seen in the shaly limestone.

These shaly beds down to this point may probably represent the middle nummulitics, but they pass so imperceptibly into lower rocks that no distinct division can be made. Below the limestone breccia band the shales become interbedded with sandstones and calcareous sandstones, and dip again steeply to the east. This series of rocks continues from Shinkai to the Idar Khél plain on the west, the dip lessening towards the east on nearing the plain.

The main mass of the rocks consists of soft shales, greenish brown to red in colour, with frequent partings of softish sandstone, buff to brown inside, but always weathering a shiny black on the surface. Some beds appear to have been altered into red coloured porcellanic, shaly limestone bands. Near Idar Khél the sandstone bands, nearly white in colour, increase in size and contain pure limestone bands, layers of sandstone and limestone alternating several times in the course of 2 or 3 feet.

In some places this series is considerably contorted, but on the whole there is a steady easterly dip throughout. There must be several thousand feet of these rocks visible in the section along the river bed. I may mention here that the black weathering of the sandstones and calcareous sandstones is very typical of middle and lower eocene rocks in eastern Baluchistán. In the calcareous sandstones there are traces of organisms, apparently *foraminifera*, but I found no fossils in any of the other sandstone or shale bands.

The Idar Khél plain is cut out of a flat anticlinal of these lower eocene rocks; in the hills east of Idak they dip again gently westwards, but here the predominance of sandstone bands is changed to one of calcareous and limestone bands, which are remarkable for the quantity of corals in them. These beds, hard grey

limestones and shales with some sandstone bands, form the hills south of the Tóchi as far west as Mahomed Khél, and to the north of the Tóchi from Mahomed Khél across to the Laram hills, and from thence down to the hills surrounding the Idak plain.

Mesozoic.

The range of hills between Idak and Mirán Sháh is formed by an anticlinal ridge which approximately strikes north and south, and which is composed of these lower eocene beds. In the core of the anticlinal a considerable thickness of massive dark grey limestone is exposed, in which I could find no fossil remains; the age of this limestone is therefore doubtful, and there is no evidence of any kind to show whether it belongs to the lowest tertiary or upper mesozoic age.

Dotoi beds.

The middle and lower eocene beds between Shinkai and Mahomed Khél are conspicuous by the general absence of undoubted nummulites: corals and the broken shells of bivalves are abundant, but *foraminifera* only occur rarely and then the traces are badly preserved. Round Dotoi, however, beds of apparently lower eocene age appear, yellow limestones with interbedded blue slaty shales, of which the limestone bands are full of fine nummulites of all sizes. These beds have no resemblance to the very white limestones and light green shales of the upper nummulitics, and very little more resemblance to the non-nummulitic rocks round Idak; in fact they show no resemblance to any of the rocks seen in the Shinkai hill section. This may be explained by the amount of igneous alteration which has taken place in the neighbourhood, and which has effaced all evidence of connection between the Dotoi rocks, the upper nummulitics north of Sheranni, and the lower nummulitics east of Mahomed Khél.

Igneous intrusion.

One is much struck on marching up the Tóchi river bed by the great quantity of pebbles and boulders of igneous rocks met with *en route*. The majority of the pebbles, even at Tóchi village, are of diorites, gabbros, and basic rocks. No indication of their being anywhere *in situ* is met with till one arrives within about 3 miles of Mahomed Khél. Here the lower eocene limestones and shales are seen to rest abruptly, but conformably on a series of beds, and are doubtless part of the latter, which are altered by igneous action, but with evidence of having been interbedded with igneous rocks, which in many cases form massive intrusions in the former. This facies of beds covers the country between Mahomed Khél and Dotoi, though it is overlaid by upper nummulitic beds north of Sheranni.

The igneous intrusions are invariably of the more basic rocks. I never found a trace of any acid rock, but diorites are very common, and they, as well as more basic forms, appear to pass gradually into the rocks which they penetrate partially. As generally happens, the beds are altered to such an extent near the junction, that no definite line can be drawn between the true shales on one hand and the true crystalline rock on the other. Throughout the whole area of igneous disturbance I never found anything but shaly beds associated with the igneous rocks.

Age of igneous series.

In some cases the shales have undergone very slight alteration only, but unfortunately I have not found any traces of fossils in beds connected with the igneous rocks, so the only clue to the age of these beds rests on their relative position to other beds. On the west the igneous series is overlaid by the lower nummulitic Dotoi beds, with the bedding more

or less parallel. On the east the Idak series of lower eocene rocks rests conformably on altered shale beds with igneous intrusions. Upper, and perhaps middle, nummulitic beds directly overlay the igneous rocks between these two junctions; the disturbance in the basal beds makes it impossible to see from a distance what connection there is between the upper nummulitics and the igneous series. It is singular that nothing but shaly beds should be found within the area of igneous disturbance. The natural conclusion to be drawn seems to be the supposition that igneous action, in the form of intrusions and deposition of ash beds, began some time before the beginning of the tertiary period; and lasted, with occasional variations causing interbedding, up to the end of middle eocene times.

Series.

The intrusive masses vary a good deal in composition. I found various forms of diorite, but the greatest variety seemed to be in the gabbros, which pass gradually into hypersthene (and diallage) rocks. Some pebbles, of what appeared to be amygdaloidal basalt, occurred in the river bed, but I never found this rock *in situ*. From the diversity of these rocks, ranging from intermediate to basic, and probably ultrabasic forms, coupled with their interbedding with shales and possibly other rocks of eocene age, it seems very probable that this series may correspond to the widespread formation of shales and igneous rocks which form large areas in Baluchistán; the Kójak shales are typical for this lithological formation, which also ranges from the later cretaceous to middle eocene times.

Description of sections.

In the absence of an accurate map, the accompanying sections (pl. 3), which are drawn approximately from east to west across the general strike of the beds, may give some idea of the arrangement of the rocks. The three sections, which are drawn to natural scale of 1 inch = 1 mile, follow the Tóchi river, mostly through the hills directly to the north of it. They do not conform quite to a straight line from east to west, but yet so closely, that they may be taken to represent a continuous section from the Dotoi country to the Bannu plain.

Section I.—To the west the Dotoi beds, considerably disturbed and contorted, form the greater part of the country, and rest near Dotoi village on the igneous series. The junction beds show a good deal of disturbance, as is natural in the immediate neighbourhood of igneous intrusions, and it is doubtful what connection there is between the beds. To the east there appears a flat basin of upper nummulitic beds, quite unaltered, composed of white nummulitic limestone, interbedded with light green shale beds. The base beds of this series is seen here and there to be drawn into the sphere of igneous action, showing that the disturbance lasted up to middle eocene times at least.

Section II.—The Idak series of lower nummulitic beds rests on the igneous facies, just north of Mahomed Khél. Igneous disturbance seems to have ceased half way through lower eocene times, leaving the upper half to the east unaltered. The only break in these beds to the east, as far as Idak, occurs in the anticlinal ridge of older limestone between that place and Mirán Sháh.

Section III.—The Idak beds form a flat broad anticlinal, which is mostly hidden under the Shamalara plain, between Idak and Shinkai, where they are seen to dip conformably under the upper nummulitic band of limestone, and this is followed normally by the lower and upper siwalik beds, which disappear finally under the Bannu plain.

On the existence of Lower Gondwanas in Argentina, by DR. F. KURTZ[1]; *translated by* JOHN GILLESPIE.

I. INTRODUCTION.

As long ago as 1875, Dr. Luis Brackebusch had described a fossiliferous formation which occurs at Bajo de Velis, and on which he has written several papers. He says[2]: "Having received from Mr. D. G. Avé Lallemant some interesting data on the existence of fossiliferous shales in the Cautana valley, I proceeded to that locality, and was not a little surprised to find some fossiliferous beds at Bajo de Velis (about a league from the entrance to the Cautana valley). This exceedingly interesting find detained me a couple of days, and I ascertained that these beds, which consist of conglomerates and argillaceous shales, had only a small vertical and horizontal extent and were unconnected with the high cliffs of the Cautana valley; they form old lake deposits in which a large quantity of plant remains have been inclosed . . . there are no animal remains found in this place." The fossils which Dr. Brackebusch sent to Dr. A. Stelzner are too badly preserved for determination, and consist solely of casts of wood.

Later on, a resident of the place, Sr. Lucio Fúnes, quarried slate for a church at Bajo de Velis, and Sr. Bonaparte, who superintended the work was the first who discovered well-preserved fossil plants, amongst them *Neuropteridium validum,* Feistm., and *Sphenozamites multinervis* non-spec. Señor Bonaparte presented the collection to Sr. D. Gualterio G. Davis, Director of the Meteorological office of Argentina, who handed them over to me for description. In 1883 Señor D. Francisco P. Moreno, Director of the Museo de la Plata, added to this collection from Bajo de Velis, which has enabled me to establish the age of the fossiliferous shales of that locality.

In describing these plants, I have followed the system adopted by W. Ph. Schimper and A. Schenk (in the 2nd part of the Handbuch der Palæontologie by K. A. von Zittel).

II. DESCRIPTIVE PART.

Dr. Kurtz describes 8 species, amongst which there are 3 new species or rather varieties of well-known Gondwana fossils.

III. SUMMARY.

The fossil flora of the argillaceous shales of Bajo de Velis, as far as known at present, consists of the following species:—

Neuropteridium validum, Feistm.
Gangamopteris cyclopteroides, Feistm.
Equisetites Morenianus, Kurtz.
Sphenozamites multinervis, Kurtz.
Noeggerathiopsis, Hislopi (Bunb.) Feistm.
N. Hislopi, Feistm. var. *subrhomboidalis,* Feistm.
N. Hislopi, Feist. var. *euryphylloides,* Kurtz.

[1] Published in the Revista del Museo de la Plata, Vol. VI, p. 117 ff.

[2] Boletin de la Academia Nacional de Ciencias (Córdoba), Vol. II, 1875, p. 188; quoted by Dr. A. Stelzner in Beiträge zur Geologie und Palæontologie der Argentinischen Republik, part I, 1885, pp. 75-76

All these species are new to Argentina, and partly also to science in general. The small number of specimens collected does not enable us to form an idea as to the relative frequency of the various species, but nevertheless it is apparent that the commonest form met with is *Noeggerathiopsis.* A similar flora is found at the Cape of Good Hope (Ekka-Kimberley beds), in Peninsular India (Kaharbari beds), in Australia (Newcastle beds, Bacchus-marsh sandstone), and in Tasmania

Kaharbari beds (India).	Bajo de Velis (Province De San Luis, Argentina).	Ekka-Kimberley beds (Cape).
Neuropteridium validum. Feistm	Neuropteridium validum, Feistm.	......
Glossopteris communis, Feistm		
G. indica, Fstm. . . .		
		Glossopteris Browniana, Brongn.
G. damudica, Fstm. . .		
G. decipiens, Fstm.. . .		
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides, Fstm.	
G. cylopt. var. attenuata, Fstm.		Gangamopteris cyclopteroides var. attenuata, Fstm.
G. cyclopt. var. areolata, Fstm.		
G. cyclopt. var. subauriculata, Fstm.		
G. buriadica, Fstm.		
G. major, Fstm.		
G. angustifolia, McCoy.		
Sagenopteris (?) Stoliczkana, Fstm.		
Schizoneura gondwanensis, Fstm.		
Sch. cf. Meriani Schimp .		
Vertebraria indica, Royl. .		
	Equisetites Morenianus, Kurtz.	
Glossozamites Stoliczkanus, Fstm.		.
	Sphenozamites multinervis, Kurtz.	
Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.	N. Hislopi var. subrhomboidalis, Fstm.	
	N. Hislopi var. euryphylloides, Kurtz.	

(Mersey coalfield). Of all these floras, that of the Kahaibari beds of the lower Gondwanas in India is closest related to the specimens found at Bajo de Velis, as may be gathered from the accompanying table, which contains a comparison of the various floras mentioned above.

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Sphenopteris lobifolia, Morr.		
S. alata Brongn. et var exilis, Morr.		
S. germana, McCoy.		
S. hastata, McCoy.		
S. plumosa, McCoy.		
S. flexuosa, McCoy.		
Glossopteris communis, Fstm.		Glossopteris communis, Fstm.
G. Browniana, Brongn.		G. Browniana, Brongn.
G. parallela, Fstm.		
G. linearis, McCoy.		
G. gangamopteroides, Fstm.		
G. ampla, Dana.		G. ampla, Dana.
G. reticulum, Dana.		
G. elongata, Dana.		
G. cordata, Dana.		
G. spathulato-cordata, Fstm		G spathulato-cordata, Fstm.
		Gangamopteris cyclopteroides, Fstm.
		G. cyclopt. var. attenuata, Fstm.
		G. cyclopt. var. subauriculata, Fstm.
	Gangamopteris angustifolia, McCoy.	Gangamopteris angustifolia, McCoy.
	G. obliqua, McCoy.	G. obliqua, McCoy.
	G. spathulata, McCoy.	G. spathulata, McCoy.
Gangamopteris Clarkeana, Fstm.		
Caulopteris (?) Adamsii, Fstm.		
		Tasmanites punctatus, Newt.
Phyllotheca australis, McCoy.		Phyllotheca australis, McCoy.
Vertebraria australis, McCoy.		
Podozamites elongatus (Morr.), Fstm.		
		Noeggerathiopsis Hislopi, Fstm.
Noeggerathiopsis media (Dana), Fstm.		

Kaharbari beds (India)	Bajo de Velis (Province De San Luis, Argentina)	Ekka-Kimberley beds (Cape).
Carpolithes Milleri, Fstm Euryphyllum Whittianum, Fstm Voltzia heterophylla, Brongn		—
Samaropsis sp		

The following may be deduced from this table with regard to the fossil plants of Bajo de Velis :—

Neuropteridium validum, Fstm., is found in the Kaharbari beds of Bengal where it represents one of the most frequent and most characteristic types. It is noteworthy that this beautiful fern is confined to one horizon only (sandstone beds) of Bajo de Velis.

Gangamopteris cyclopteroides. Fstm., (5 varieties) and 4 other species are the commonest and predominating forms which occur in the Talchir-Kaharbari beds; in the next succeeding horizon, the Damuda division, only some small forms of this genus survive, but they disappear completely higher up. In Africa *Gangamopteris cyclopteroides* has been found only in the lower beds of the "Karoo" formation (the "Ekka-Kimberley" beds) and this is the only species of *Gangamopteris* known in Africa. In Tasmania *G. cyclopteroides* has been found with its varieties, *G. attenuata* and *G. subauriculata*, all in the Mersey coalfield. *Equisetites morenianus*, Kurtz, may be compared with the various remains of the families of the *Equisetaceæ*, and of the Schizoneuræ found in the Talchir Kaharbari beds, and very probably belongs to the genus *Schizoneura*, which would clear up an important point connected with the Damuda-Panchet system; in Australia the genus *Phyllotheca* is represented in the group of the Schizoneuræ. *Sphenozamites multinervis*, Kurtz, stands isolated and cannot be compared with forms elsewhere.

Noeggerathiopsis, Hislopi, Fstm., occurs in the Talchir-Kaharbari beds and in the middle Gondwanas (frequently at Damuda and South Aurunga); in the upper Gondwana (Rajmahal series) no species of *Noeggerathiopsis* exist (although they occur at Tonkin). In Africa *N. Hislopi*, Fstm., is only seen in the Kimberley beds, and in Tasmania the species has been found in the Mersey coalfield.

Bajo de Velis.	Ekka-Kimberley beds.	Kaharbari bed.
Neuropteridium validum, Fstm.		Neuropteridium validum, Fstm.
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides, Fstm. var.	Gangamopteris cyclopteroides, Fstm.
Equisetites Morenianus, Kurtz.		
Sphenozamites multinervis,		

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Brachyphyllum australe, Fstm. (?); cf Schimper-Schenk, Palæophytologie, pp. 331, 306).		

where it is associated with another species of the same genus, *N. media* (Dana), Fstm. This last and two more species have been likewise found in New South Wales.[1]

The better to compare the relations which exist between the fossil flora of Bajo de Velis and the plants of the other areas, which we have had under consideration, I have compiled a table of the data available.

From the data given in the following table it may be concluded that the fossil flora of Bajo de Velis belongs to the same geological horizon which holds the other 5 plants mentioned, and that its prototype is the flora of the Talchir-Kaharbari beds of the lower Gondwanas. The palæophytologist O. Feistmantel has already discussed at some length the relation which the lower gondwanas, and the strata in Africa and Australia, occupy to the recognized horizons, especially those of Europe, and has arrived at the conclusion that the formations in question belong to the Permian system, that is to say, that they represent the close of the palæozoic group, a conclusion which several Australian geologists have endorsed, and which in my opinion may be generally adopted with reference to the age of the beds in Argentina[2] :—

[1] The genus *Glossopteris*, so abundantly represented in the various strata of the Gondwana system in South Africa, India and Australia, where it appears for the first time in the upper carboniferous strata (Queensland) and rises to the upper Trias or the lower Jurassic (' Jubbulpore group ") is completely wanting in America (as also in Europe); *Glossopteris* is chiefly distinguished from the genus Gangamopteris by the existence on its fronds of a median vein, which character is completely absent in *Gangamopteris*.

[2] It must be mentioned here that this view had practically been adopted by the members of the Geological Survey of India some time before Dr. Feistmantel would admit it himself. (Director Geological Survey of India.)

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Gangamopteris (1 spec.).	Gangamopteris (3 spec).	Gangamopteris cyclopteroides, Fstm., cum var. et. 3 spec. alt.

Bajo de Velis.	Ekka-Kimberley beds.	Kabarbari beds.
Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.		N. Hislopi var. subrhomboidalis, Fstm.
N Hislopi var. euryphylloides, Kurtz.		

Up to date we know of three rock-formations in Argentina which have yielded fossil plants. The first is that of Retamito in San Juan, which corresponds to the lower carboniferous (Culm) as Dr. L. Szajnocha [1] has already shown; then follows the flora of Bajo de Velis which has no species in common with the preceding formation nor with the following series. The latter occurs in the neighbourhood of Cacheuta, Challas and Uspallata in Mendoza, at Mareyes in San Juan, and in the Escalera de Famatina in La Rioja. The fossils found at the latter places belong to completely different flora, which Professor H. B. Geinitz has already determined as belonging to the rhætic,[2] a conclusion confirmed by Dr. A. Stelzner [3] and also by Dr. L. Szajnocha[4].

To the same epoch belong the fossil plants, which are found in the Stormberg beds (Upper Karoo) of South Africa; in the Tivoli-Ipswich beds of Queensland; in the Wianamatta-Hawkesbury beds of New South Wales; and in the Jerusalem beds of Tasmania: that is to say, that these fossil plants occur in horizons between the upper triassic and lower jurassic systems. In India the lower beds of the Rájmahál series (Upper Gondwanas) correspond more or less to the rhætic system.

In the following table I have arranged the plant-bearing beds of Argentina according to their geological horizons:—

Series of beds at Cacheuta, Challas, Uspallata, Marayes, Escalera de Famatina.	Rhætic.
?	Trias.
Bajo de Velis series.	Permian.
?	Upper carboniferous.
Retamito series.	Lower carboniferous (Culm).

[1] Revista, Vol. VI, p. 119; see also Stz. Ber. Kais. Akad. d. Wissensch. Wien, Vol. C, pt. 4, p. 203 (Dir., G. S. I.).

[2] Ueber rhætische Pflanzen und Thierreste in den Argentinischen Provinzen La Rioja San Juan und Mendoza: 1876 (Palæontographica Suppl. III.).

[3] Beiträge zur Geologie und Palæontologie der Argentinischen Republic, I: 1885, pp. 68-82.

[4] Ueber fossile Pflanzenreste aus Cacheuta in der Argentinischen Republic. Sitz. Ber. Kais. Akad. Wiss. Wien., Vol. XCVII, pt. 1, 1888, pp. 219-245.

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Noeggerathiopsis (1 spec.).		Noeggerathiopsis Hislopi, Fstm.

Note by the Director, G. S. I.—The evidence afforded in the above paper has such a strong bearing on the age and relations of the most important of all our rock-formations of India, namely the coal-bearing Gondwanas, that it appeared advisable to have it translated from the Spanish original, which has been ably done by Mr. John Gillespie, to whom our acknowledgments are due.

One of the chief points of interest in connection with the discovery of Gondwana plants in Argentina lies in the fact that there we have an unquestionable lower carboniferous series (Retamito) in the neighbourhood of which (and probably unconformably to it) a series of beds is found, which contains well known lower Gondwana species of plants, thereby limiting the geological range of the lowest beds of it, at all events to upper carboniferous at most, which is a further confirmation, long ago and independently arrived at by the authors of the "Manual" (1st edition) and generally adopted by the Geological Survey of India.

Notes from the Geological Survey of India.

I. *Central India, Rewah.*—Mr. Oldham with Mr. Datta have continued their surveys in Rewah, and some of the results of their work have already been noticed in my annual report and in the "Notes," Records, part 2; with regard to the Vindhyans and underlying rocks no specially new facts have come to light; but, on the other hand, Mr. Oldham has latterly been engaged in the survey of a patch of Gondwanas, which contained several rather fair coal-seams, though few over three feet in thickness. The total extent of the surveyed area of the coal-measures is about 200 square miles, and it is situated east of the Mohan river, shown in sheet 476 of the Rewah survey.

Near their western limit they are covered by red ferruginous sandstones and shales, whose extent has not been determined. The Barakar age (already determined correctly by Mr. Smith) is clearly shown by the fossil contents, amongst which are *Vertebraria*, *Glossopteris*, *Schizoneura*, etc. Two coal-seams of 6 feet and 5 feet 6 inches thickness were found by Mr. Oldham; the former is 1½ miles south-west by west of Ujeini, the latter, 2 miles north of Amlia, both places near the eastern edge of the standard sheet 476.

II. Madras.—Mr. Middlemiss continued his researches in the Salem district and reports in February.

(1) *Magnesite and ultra-basic rock of Valaiyapaddi.*—The magnesite is present in very small quantities. The rocks associated with it entirely resemble those at the north-west end of Kanjamallai, so far as their appearance in the field goes. Forming a long low ridge, running east and west from Valaiyapaddi, there are interesting examples of the above type in close association with a very acid rock, namely, a coarse graphic granite composed almost entirely of pink orthoclase and quartz. Both rocks are intrusive among the basal gneisses of that area in parallel lines. Some good instances of this are to be found west of Valaiyapaddi. The graphic granite was probably intruded last.

(2) *Charnockite, south of Salem.*—Between Muttu Kalipatti and Salem on the Namakal-Salem road a great exposure of charnockite occurs. From its position, strike, and general appearance it is a continuation of the Shevaroy Hills massif.

(3) *Chalk Hills.*—The final few days spent at the Chalk Hills enabled me to secure some "camera" sketches and photographs. As a whole, the aspect of each magnesite area is that of a series of concentric ellipses (roughly speaking) of rocks of varying composition and basicity. At the centre of each area occurs the chromite in veins among the dunite and serpentine; surrounding this is a paler dunite zone (almost pure olivine, or partly or wholly converted into magnesite). Surrounding this again is a small ring of rocks containing olivine and pyroxene with sometimes biotite. Surrounding this at certain points come rocks like the last, but with felspar and quartz in small quantities. Finally, surrounding the whole area come great ridges of hornblende-garnet rocks set among and with the ordinary gneisses of the country.

(4) *Corundum localities, Coimbatore District.*—The corundum localities visited in Coimbatore embraced Selengapalaiyam near Kavanthapatti where the mineral is only sparingly found and picked up from the surface after heavy rain. It is similarly found at Gopichettipalaiyam in one small field. The locality of Siva Mallai is the best that I have yet seen. The mineral is regularly worked for and occurs as large hexagonal prisms scattered about in an extremely coarse biotite granite with pink felspar. The latter follows along the north-west side of a range of low gneiss hills, a continuation of the Siva Mallai. The corundum is chiefly found on the margins of the granite veins.

III. Baluchistán.—During February Mr. Smith examined the high range between the Lúni plain and the Zhób territory. This range is apparently formed of massive jurassic limestone, containing ammonites; its thickness is very great, and in the Wat pass, which leads through the centre of the range, it is quite 2,000 feet, all within sight, and the base is not exposed.

This grey, massive limestone is overlaid by the neocomian belemnite beds, consisting of yellowish to pink, light green and white shaly limestones and shales,—conformably apparently. The entire area near Mekhtar is formed of these beds, which yielded belemnites in abundance besides some ammonites.

This neocomian horizon is overlaid by a great series, which Mr. Smith was enable to divide further, but which seems to have varied a good deal lithologically; the middle of the series apparently contained nummulitic limestone beds, and the uppermost beds were capped by the white nummulitic limestone of the Spintangi

beds. Some of the beds of this great series appear to be derived from volcanic material, and even basaltic rock was met with

There can be little doubt but that this sequence of beds represents the great belt of strata, which extends from south of Hindu Bágh, north of the Loralai hills along the southern side of the Zhób valley, and which show such a well pronounced flysch character. The lowermost beds are upper cretaceous, whilst the whole lower and middle nummulitic division of the tertiary system is represented.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

CALCUTTA;
The 1st August 1895.

DONATIONS TO THE MUSEUM.

FROM 1ST MAY TO 31ST JULY 1895.

Gold washed from sand, and sand containing gold, from 6 miles north-east of Hopin, Muh Valley Railway, Upper Burma; and a specimen of fossil wood from west of Hopin, Muh Valley Railway, Upper Burma.

PRESENTED BY A. F. JOHNSTON, SUPERVISOR, P. W. DEPT., RAILWAY BRANCH, MUH VALLEY RAILWAY, UPPER BURMA.

Three specimens of cassiterite from Cornwall, England.

PRESENTED BY J. R. HOSKEN, PENBRO BREAGE, CORNWALL.

A specimen of concretionary clay, from Katni, Jabalpur District; and decomposed felspathic breccia cemented with calcite, from Moosrakand, Raniganj.

PRESENTED BY JAS. CLEGHORN, CALCUTTA.

Pyritous dolomitic limestone, from the Khesra Valley, Waziristan.

PRESENTED BY PANDIT RAM RAKHAN MISSER, TRANSPORT AGENT, 2ND BRIGADE, WAZIRISTAN FIELD FORCE.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1895.

Titles of Books. *Donors.*

BECK, *Dr. Ludwig.*—Die Geschichte des Eisens. Abth. II, lief. 7. 8° Braunschweig, 1895.

BLAKE, *J. F.*—Annals of British Geology, 1893. 8° London, 1895.

BONNEY, *T. G.*—The Story of our Planet. 8° London, 1893.

BOSE, *P. N.*—The Economic Results of the Mergui Coal Exploration. Flsc. Pam.

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BRONN, *Dr. H. G.*—Klassen und Ordnungen des Their—Reichs. Band III, lief. 18-20, and V, Abth II, lief. 41-43. 8° Leipzig, 1895.

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THE AUTHOR.

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CHEWINGS, *Charles.*—Beiträge zur Kenntniss der Geologie Süd und Central-Australiens. Inaugural Dissertation. 8° P. Heidelberg, 1894.

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FRECH, *Dr. Fritz.*—Die Karnischen Alpen. 8° Halle, 1894.

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JACK, *Robert L.*—Artesian Water in the Western Interior of Queensland. 8° Pam., Brisbane, 1895.	THE AUTHOR.
JAEKEL, *Dr. Otto.*—Die eocänen Selachier Vom Monte Bolca. 4° Berlin, 1894.	
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LATOUCHE, *Tom D.*—Boring exploration in the Daltonganj Coal-Field, Palamow. Flsc. Pam., Simla, 1890.	
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MARTEL, *E. A.*—Les Abimes. 4° Paris, 1894.	
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„ Report on the Lead Mines in the Pinlebu Sub-division, Katha District. Flsc. Pam., Calcutta, 1891.	
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„ Memorandum on the possibility of finding Petroleum near Sukkur on the Indus. Flsc. Pam., Calcutta, 1891.	
„ On the mode of occurrence and probable distribution of Artesian water in the valley plains of the Quetta and Pishin Districts. Flsc. Pam., Calcutta, 1891.	
„ Preliminary Report on the oil locality near Moghal Kot, in the Sherani country, Baluchistan. Flsc. Pam., Calcutta, 1890.	
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THE EDITOR

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RECORDS

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1896. February.

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1895.

The actual area which was geologically surveyed during the past year is much below the amount which could have been estimated for under favourable circumstances, though perhaps not below the amount of surveys in square miles, done during each of the last few years. This, however, may easily be accounted for by the fact that not only were several officers withdrawn from survey work proper and employed on so-called economic inquiries, but there were several vacancies on the staff, which could only recently be filled up.

At the beginning of the year the officers were distributed as shown in the last Annual Report on page 1 of the Records, Vol. XXVIII.

Mr. H. H. Hayden joined the Department as Assistant Superintendent on the 21st February, too late to take up field work, and he was therefore detained at head-quarters to learn the vernacular language and to assist in laboratory work.

Messrs. Vredenburg and Grimes were appointed Assistant Superintendents by the Secretary of State to fill vacancies on the staff; both jointed head-quarters on the 16th October 1895.

During the year three officers proceeded on furlough, namely, Mr. LaTouche on the 19th March, Mr. Bose on the 15th May, and Dr. Noetling on the 1st July 1895.

At the beginning of the present camping season the staff of the survey was distributed as follows:—

Mr. R. D. Oldham with Messrs. Datta, Vredenburg and Grimes	Rewah.
Mr. Middlemiss with " Smith	Madras.

A

Mr. HOLLAND . .	. Head-quarters.
„ HAYDEN . .	. Burma.
Mr. ANDERSON with Dr. WARTH and LALA HIRA LAL	Chota Nagpore.
LALA KISHEN SINGH .	. Baluchistán.

During the hot weather months and the rainy season most of the officers returned to Calcutta to work up their repoits and maps; Mr. Middlemiss returned to Madras at the beginning of the monsoon to continue field work.

Mr. Oldham, with Mr. Holland, proceeded to Naini Tal at the close of the monsoon to ieport on the stability of the hill-sides of that station.

I myself proceeded on inspection when opportunities offered, and I performed the following tours :—

During March to Chota Nagpore and Central Provinces.

During June to Naini Tal at the iequest of the Government of the North-Western Provinces.

During July and August to the Central Provinces and Madras.

During October to Naini Tal.

Summaiy of work accomplished.

In the following pages I give an outline of the work performed in the field and laboratory.

Bengal.
Mr. Anderson.
Dr. Warth.
Lala Hira Lal.

As already repoited in my Annual Report for 1894, the mineralogical survey of Chota Nagpore has been begun by Mr. Anderson, the mining expert of this Department. During the camping season ending during April of 1895 he explored a considerable area of Chota Nagpore. He made traverses in many directions, beginning with the countiy around Borobhum, and from thence to Dhadka, Moholia and Chaibassa. East of Borobhum, to a distance of about 12 miles, the transition rocks are much intruded by dykes and masses of a hornblendic rock, probably diorite. Associated with these intrusions are innumerable quartz-reefs, many of which were tested, but show no traces of gold. Almost all the reefs of this area have generally a north and south strike, many of them occurring as joint reefs in the dykes. In the country between the Cupergadi Ghat and Chaibassa, similar dykes associated with quartz-reefs occur, but they also show no traces of gold.

I visited Mr. Anderson during March, when his first and rapid traverses were drawing to a close. A quotation from his February report will afford an idea of the work and the geological nature of the ground gone over. " During the month of February I made an examination of the country around Chaibassa, Seraikela and Sim. At the first-mentioned place the boundary between the transitions and metamoiphic series runs close past the town in a north and south direction. In the neighbourhood of this boundary the rocks, particularly those of the transition seiies, are seamed with quartz veins. To the north and north-west of the town the outcrops of these veins are not at all well defined but usually form a series of small circular or elongated hills, composed superficially of nothing but small fragments

of quartz. In some parts these hills occur in numbers close together and cover considerable local areas. Almost anywhere in such areas the broken quartz debris, when crushed or washed, show minute traces of gold. The absence of defined outcrops would materially increase the expense and time of prospecting this area, because so much work would require to be done in trenching through the superficial debris to get at the actual reef outcrops."

During this camping season prospecting work has begun in earnest, sufficient funds having been sanctioned by the Government of India for the purchase of the requisite plant, tools, etc. A five stamp prospecting battery with all the necessary outfit has been procured, workmen are being engaged and practical investigations are being carried out in three separate mining camps. So far the traces of gold found in quartz-reefs are not encouraging, but nothing definite can be said about the prospects of finding it in payable quantities eventually, as only 70 reefs have been examined up to date.

An interesting and probably useful find of blue corundum has been made by Dr. Warth on the Balarampur-Borobhum road; it occurs in a vein of kyanite, and when opportunity offers this find will be followed up.

Rewah.
Messrs Oldham, Datta, Vredenburg, and Grimes.

The area mapped during the field season of 1894 to 1895 was very small, little more than 700 square miles; this insufficiency may be accounted for inasmuch that both officers (Messrs. Oldham and Datta) were new to the district and were only partially acquainted with the rocks they met with during the progress of work. A considerable time was also lost by Mr. Oldham in inspecting previous work done by Messrs Hughes, Bose and Smith in Rewah and in trying to reconcile it with his own observations and views. The result has led to some modifications of views held hitherto with regard to the so-called Vindhyan system; the chief point made out is the separation of the Lower Vindhyans (Sub-Kymores) from the Upper Vindhyans. The latter will, according to Mr. Oldham, henceforth represent the Vindhyan system proper, whilst the strata below them and above the transition rocks are to be called, as was done by Mr. Medlicott originally, the Semri series. The Vindhyans rest unconformably upon the Semri series, but it will have to be established whether in spite of the unconformability, which is only seen locally; the two series are separated from each other by a general break in deposition of the beds composing the same. Mr. Oldham has stated his views in a paper in Records, Vol. XXVIII.[1]

Besides working on the Vindhyan rocks Mr. Oldham also examined a small coal-field in the eastern part of Rewah which Mr. Smith had surveyed some years ago; the Barakar age of the rocks has now been established, as they contain *Vertebraria, Glossopteris, Schizoneura,* etc. Two coal-seams have been found, respectively of 6 feet and 5 feet 6 inches thickness; the former is $1\frac{1}{2}$ miles south-west by west of Ujeini, the latter 2 miles north of Amilia, both places near the eastern edge of sheet 476.

Mr. Datta devoted the greater part of his attention to mapping the lower Vindhyans, or, as Mr. Oldham calls them once more, the Semri series. The work has been done in detail and some additions are made to our knowledge of

[1] p. 139.—On some outliers of the Vindhyan system south of the Son and their relation to the so-called lower Vindhyans.

this series. A preliminary description of the area has been given by him in a paper in the Records, Vol. XXVIII.[1]

During November Mr. Oldham took up work once more in Rewah, his staff being augmented by Messrs. Vredenburg and Grimes. So far the work of the party has not progressed far enough to add new facts to those already reviewed.

Central Provinces. Mr. P. N. Bose.

Mr. Bose continued work south-west and west of Raipur in the Central Provinces, from where he returned to head-quarters on the 6th April. He sent in a progress report from which it appears that the main features of the geological structure of that portion of the Central Provinces consists of a base of crystalline rocks, granites, and gneisses with great intrusions of felsites, on the denuded surface of which lie patches, often of large extent; of "Vindhyans"; two lithologically distinct facies of the lower division of this system have been distinguished by Mr. Bose,—the eastern or Chattisgarh facies and the western or Bhan dara rocks. The former are already known as the "Chandarpurs," whilst he proposes to call the latter the "Bagh Nadi" sandstones, a distinction which I do not consider necessary, as apparently these two facies are of the same age. There can be little or no doubt whatever that the entire sequence of beds in both areas belongs to the lower Vindhyans, as known hitherto, and my own inspection of these rocks is in conformity with this view.

Mr. Bose had taken up work in the Central Provinces as early as 1884, and has always insisted on having discovered an unconformity between the lower Vindhyans and the so-called Chilpis, a series of strata doubtfully correlated with transitions elsewhere. One of the localities specially mentioned by him was the country around Warorband, about ten miles south-east of the Dongarghar station on the Bengal-Nagpur Railway. Mr. Bose had been several times over this area, and during last field season he reported that he had obtained confirmatory evidence of his former assertion. I may here mention that Mr. Medlicott, who knew the ground, strongly differed from this view, but that Dr. King, although he thought (Records, XVIII, page 190) that the evidence was unsatisfactory, on a later occasion expressed his opinion that this unconformity had been established. The question of unconformity or otherwise remains to-day much where it was before, but during a short inspection of Mr. Bose's work during March I ascertained that the so-called Chilpi beds have no existence at Warorband itself. Believing that an inspection of that locality which he had repeatedly visited, and the survey of which he had revised as late as last season, would afford a fair test of his work, I proceeded to the place in March last, and during a few days' stay walked over the neighbouring country,—which is fairly open,—in company with Mr. Bose. I started from Dongarghar station, which I may here mention is situated on granite, which forms particularly characteristic "tors" and rugged hills in the neighbourhood, some of which are crowned with temples. The granite is seen *in situ* not only there but for miles around, and the road (ten miles) to Warorband passes almost entirely over it. There are dykes and intrusions of felsites and diorites seen in this area along with numerous and conspicuous quartz-reefs.

According to Mr. Bose we should have a sequence of older beds (Chilpis,

[1] p. 144.—Notes on a portion of the lower Vindhyan area of the Sone Valley.

consisting of grits and conglomerates, etc.) dipping at a higher angle below the Chattisgarh lower Vindhyans, the former being associated with eruptive rocks.

What I actually found was that the country about west of Warorband consists of granite, with wide belts and intrusions of felsites and diorites; these igneous rocks have long ridges of reef-quartz running nearly north and south, and on an abraded surface of these rocks rest immediately beds of the lower Vindhyans (so-called), which form the basin-like Chattisgarh series of strata, the western margin of which is slightly raised, thus dipping from 20 to 30° east and east-south-east, gradually flattening out, and even in some cases forming undulating anticlinals. The lowermost beds consist of brownish-red to purplish indurated quartz-sandstones, with strings of grits and in some places breccias and conglomerates, which strongly reminded me of the Rotas (Sone) basal conglomerate of the lower Vindhyans. The grits are not confined to beds nor to the base of the series, but as is usual in such a lithological facies, occur in strings and irregular beds at various horizons. The upper beds of this system consist of the Chattisgarh limestones, with which we have no concern here. Nowhere could be discovered any sedimentary or metamorphic rock which might have been identified with an older system than the Vindhyans, and although I am quite ready to admit that the igneous series of rocks which forms the base of the lower Vindhyans here, may be intrusive in a "transition" system, of which the Chilpis may be a local development, yet neither at Warorband nor anywhere in that neighbourhood is there any evidence of such a system, and the lower Vindhyans rest directly upon the granitic and in other places upon a felsitic or dioritic base. It seems that Mr. Bose had taken four distinct rocks as parts of the assumed "transition" series; first, the (probably) pseudomorphic quartz, which forms such numerous and most conspicuous reefs in that area and which in some places forms actually the base of the lower Vindhyans, and which being much crushed at places, has occasionally the appearance of a breccia and even grit,—that is to say, if not very closely observed; secondly, for some reason he looked upon the basal grits and conglomerates of the lower Vindhyans, where raised at a higher angle, as forming an older and unconformable series of rocks to the same beds, where the dip flattens out, or is even slightly reversed in cases of shallow synclinals, and this was the case at a point east of the Warorband lake itself; thirdly, an exposure of diorite weathering concentrically and showing that leafy condition, which in hand-specimens is often at first misleading, was mapped as intrusive in phyllites, the latter being the weathered and pseudoschistoze portion of the diorite; and lastly, Mr. Bose had identified and mapped as grits and shales of the Chilpis, a long and most conspicuous ridge made up of typical felsite. After a most careful inspection I may assert most confidently that at all events there are no "transitions" or "Chilpis" or any older sedimentary strata below the lower Vindhyans at Warorband, but that the latter rest directly upon an eroded surface of igneous rocks. That the "Chilpi Ghat series" may elsewhere underlie the lower Vindhyans unconformably is thereby not disproved of course.

The continuance of the geological survey of the Central Provinces has to be postponed owing to the fact that Mr. Bose has gone on two years' furlough.

N.-W. Provinces. Naini Tal Messrs. Oldham and Holland.

After return from field work in Rewah and before the beginning of the rainy season, Mr. Oldham was deputed to Naini Tal to serve as member on the Committee appointed to report on the safety of Government House Hill. The examination was conducted during May and most of June; Mr Oldham has sent in his report to the Government of the North-West Provinces, but the following extract from his diary for June expresses his views in outline: "The facts collected, when compared with those observed on my previous examinations leave no doubt that there is a steady downhill creep of the outer portion of the hill for a depth of probably about 50 feet. The main surfaces of separation unfortunately reach the summit under the Government House and the constant settlements which have taken place in the past, at an annually increasing rate, impressed me with the danger of a further settlement taking place, which might be sufficient to endanger the house."

As other members of the Committee dissented from this view, the Government of the North-West Provinces requested that I should give my opinion, and I proceeded to Naini Tal accordingly. Whilst I fully agree with Mr. Oldham in believing that the entire hill slope below Government House is in a more or less dangerous condition and that some day slips on a large scale may occur there, yet I did not feel convinced that distinct proofs existed of later and more extended developments of certain cracks in the hill, which had been reported on many years ago. In the absence of positive proofs that the hill-side exhibited greater signs of danger now than it did for some years past, I did not advise the Government to evacuate the hill, but to stringently enforce certain recommendations which had been made by previous committees, and also to carry out extended drainage works. One of my reasons in advising Government thus, was, that immediately after the rains a further and more detailed examination of all the hill-sides of Naini Tal was to be made by officers of the department, when the question would be finally settled. This was done during October and part of November of this year. A large scale contoured map of the station had been made by the Survey of India, and Messrs. Oldham and Holland conducted their detailed inquiries, which will be embodied in an exhaustive memoir and which ought to dispose finally of the question of the safety of this hill-station.

Madras. Messrs. Middlemiss and F. H. Smith.

The investigations, chiefly of a petrological character, which Mr. Middlemiss pursued during 1894, were continued also during the past year, and they have added much to our knowledge of the occurrence and distribution of the magnesites and corundum o the Madras Presidency. Many of his observations are of great interest and have therefore been more fully dealt with in "notes" published in the "Records." He has sent a preliminary report, rather fully worked out, which will be published in the "Records." This cold season he is assisted by F. H. Smith, and it was hoped that the special work on which Mr. Middlemiss has now been engaged for about two years would be accelerated, but unfortunately Mr. Smith has been seriously ill with fever since his arrival in the Madras Presidency.

Sind. Mr. LaTouche. Lala Hira Lal.

The trial boring for oil which was commenced two years ago, progressed satisfactorily, if slow, till the 19th March of the past year, on which date Mr. LaTouche handed over the work to Lala Hira Lal, Sub-Assistant of the Geological Survey of India,

and proceeded on furlough for eighteen months. The latter was only very few days responsible for the direction of the boring, arrangements having been made to hand the same over to the North-Western Railway authorities, which was finally effected on the 25th March. Mr. LaTouche has given a short report on the boring in the May number of the Records.

The personnel of the works consisted of Mr. LaTouche with Lala Hira Lal of the Department, the latter only having joined 25th October 1894; and two American drillers, Messers. Cremer and Eady. The last named was engaged at the special representation of Mr. LaTouche, who urged the advisability of working more continuously.

When Mr. LaTouche handed over the boring to the North-Western Railway authorities it had reached a depth of about 1,100 feet, and since then it was brought down to 1,500 feet, without, however, obtaining any trace of oil. The chisel has passed through some limestone bands latterly, which may be the beds of the lower nummulitic, but to be certain, I have recommended that the boring be brought about 200 feet lower.

Salt.—While superintending the boring at Sukkur, Mr. LaTouche had occasion to examine a very interesting occurrence of rock-salt in nummulitic limestone. The spot where this mineral is found is about half a mile south-east of the village of Aror, which lies at about 4 miles east of Rohri on the left bank of the Indus.

Baluchistán and North-Western Frontier.
Mr. F. H. Smith.
Lala Hira Lal.
Lala Kishen Singh.

During February Mr. Smith examined the high range between the Lúni plain and the Zhób territory. This range is apparently formed of massive jurassic limestone, containing ammonites; its thickness is very great, and in the Wat pass, which leads through the centre of the range, it is quite 2,000 feet, all within sight, and the base is not exposed.

This grey, massive limestone is overlaid by the neocomian belemnite beds, consisting of yellowish to pink, light green and white shaly limestones and shales,—conformably apparently. The entire area near Mekhtar is formed of these beds which yielded belemnites in abundance, besides some ammonites.

This neocomian horizon is overlaid by a great series, which Mr. Smith was unable to divide further, but which seems to have varied a good deal lithologically; the middle of the series apparently contained nummulitic limestone beds, and the uppermost beds were capped by the white nummulitic limestone of the Spintangi beds. Some of the beds of this great series appear to be derived from volcanic material, and even basaltic rock was met with.

Later on, after returning from the Tochi pass, to which he was deputed on special duty, he traversed the country lying between Déra Gházi Khán and Ziárat. His observations were only made *en route* and consequently must be fragmentary. He reports that between Karwada to Mekhtar he traversed about 30 miles of middle and lower nummulitic rocks, sandstones and limestones with numerous shale partings. East of Mekhtar these beds rest apparently conformably on "belemnite beds" (upper cretaceous). From thence to some distance west of Loralai he observed all the rock facies which we already know to exist in those parts, *i.e.*, sections from the jurassic limestone to nummulitic, but he had no time then to further examine the country, the season being too far advanced. The high range north of the Sháhrig valley, generally known as the Kaliphát range and which rise

to upwards of 10,000 feet, seems to show in places a complete section beginning with the jurassic massive limestone, overlaid by cretaceous rocks and capped by the lower nummulitic limestone. The existence there of jurassic beds is an interesting fact.

During June Mr. Smith examined some of the high ground west of Ziárat, especially the Pil range, through which a fine section is laid bare by the tangi (defile) north of Mangi; the range is made up of a great thickness of massive limestone (about 3,000 feet), which he identifies with the jurassic beds seen further east, and which is overlaid by well-developed "belemnite beds" (*i.e.*, lower and upper cretaceous), the whole being covered by the hard grey lower nummulitic limestone.

Hills east of Sibi.—Lala Hira Lal, after handing over the Sukkur boring to the North-Western Railway authorities, was ordered to Baluchistán, and to survey the low ranges east of Sibi. He was engaged during May and June in geologically surveying the low hill ranges east and north-east of Sibi, which task was successfully accomplished. The rocks met with belong to the tertiary system and recent deposits. Upper nummulitic limestones were met with occasionally, but the rest seem to consist of very large thicknesses of Siwalik sandstones, shales and conglomerates only. Some fossils were collected by this officer, but apparently good specimens are very rare and as usual in those parts, the Siwaliks contain little more than fragmentary remains of vertebrates, amongst which are very few which will permit a specific determination.

Hills near Quetta.—Lala Kishen Singh was engaged during the last quarter of the year in examining the south-western extension of the Murdar hill near Quetta, which he found to consist of massive limestone, probably of jurassic and lower cretaceous age, the only clue to its structure apparently being a band of upper cretaceous belemnite beds. He also examined the northern end of the Chehiltan range; the section of it had already been worked out during previous field seasons. It includes strata from the upper jurassic to lower nummulitic age.

Tochi Pass.—Mr. Smith was deputed to join the Tochi delimitation camp during February and March, and he has furnished a short preliminary report,[1] the main features of which shew that the section seen along the Tochi route resembles closely that of the Sulaimán section, and that some of the rocks are very similar to those found in Baluchistán.

The section commences on its eastern limit with a series of Siwaliks, which dip eastwards under the recent deposits of the Bannu plain. The Siwaliks, both upper and lower, are of immense thickness, the lower beds alone showing a normal section of vertically dipping strata of 2 miles in length. Below them is a thin band, 170 feet, of white nummulitic limestone, beneath which follows a great thickness of shales and limestones, in which Mr. Smith did not discover any determinable fossils, but which he suspects to represent the entire middle and lower eocene divisions. The lowest beds of this sequence form an anticlinal ridge of dark grey unfossiliferous shaly limestone of unknown age. These lower tertiary rocks form a wide belt, some 30 miles from east to west, and include the Laram range. Near Mahomed Khél, the lower beds of the series become suddenly mixed with intrusive and also interbedded igneous rocks, chiefly diorites, gabbros, and serpentines. North of Sheranni this igneous series is overlaid by white nummulitic limestone

[1] Records, Vol. XXVIII, page 106.

and shales, and at Dotoi, 10 miles west of Sheranni, the same igneous series is overlaid by blue slaty shales with thin nummulitic bands.

In some respects this description recalls the flysch-like series of rocks of the Kōjak and Peshin ranges.

Burma.
Dr. F. Noetling.
Dr. H. Warth.
Mr. H. H Hayden.

Oil.—The inquiry into the occurrence and nature of the earth-oil of the Yenangyoung neighbourhood has at last been brought to a successful close by Dr. F. Noetling, who was engaged on the work for several years but with interruptions. That officer returned from Burma in March of this year and has handed in a very voluminous and exhaustive report, fully illustrated with sections, views and maps now in the press.

Gems.—Dr. Warth was deputed to Burma to report on a tract of country northwest of Mogoung, where rubies had been discovered, and which area had been declared a "stone tract" by the Government of Burma. A long delay at Rangoon, owing to a medical examination which that officer had to undergo, prolonged the inquiry far into the hot weather and had therefore to be confined to the "stone tract" alone.

His report may be summed up as follows: The area consists of crystalline rocks, chiefly granitic and igneous, inclosing patches of metamorphic rocks amongst which a crystalline limestone is especially noticeable, which contains the same minerals as found in the Mogok and Sagyin areas, and which is probably also here the original matrix of the rubies, which are now dug up by natives from the surrounding alluvium. The latter forms the "stone tract" proper, may be about ten square miles in extent, and does not seem to be very rich in gems.

Mr. H. H. Hayden was posted to Burma during this field-season, and he started work in the ruby-tract of the Sagyin hills during November. His researches carried out under somewhat trying conditions, which the dense vegetation aggravates, are of considerable interest. The main results obtained so far are as follows:—

The rocks of the area are chiefly of two kinds, namely crystalline, consisting of gneiss and schists, and overlying the same, limestone which is considerably altered and contains many and interesting minerals, including spinel and ruby. The latter occur chiefly in a veinstuff which fills joints and fissures, and out of which the natives obtain the gems. One of the most interesting facts established by Mr. Hayden is that the limestone rests on the schists and gneiss, the junction being marked by the presence of a conglomerate associated with a limestone breccia, thus proving without doubt that this coarsely crystalline limestone is of sedimentary origin.

Publications.

Vol. II of Series XIII of the Palæontologia Indica has at last been published, and Dr. Waagen's description of the fossils from the Ceratite beds will henceforth form a standard work on the lower trias of the Salt Range.

The publication of this classic volume was so long delayed and so much new light has been shed upon the lower trias fauna of India within recent years, that a review of the results of Dr. Waagen's researches becomes imperatively necessary. I am informed that the learned Professor is preparing such a summary, which will probably be first published in Europe.

Of the Series XV on Himálayan Fossils, part 2 of Vol. II has already appeared, descriptive of the Cephalopoda of the Muschelkalk. The material which Dr. Diener had at his disposal, which includes all the specimens collected from those beds in the Himálayas up to date, is so complete that we are in a position to correlate these beds with perfect accuracy. It is a matter of especial satisfaction to me that the examination of these interesting fossils has confirmed my division of the trias of the Central Himálayas, founded as it was, chiefly upon stratigraphical grounds.

Part 1 of the same volume, on the Cephalopoda of the lower trias by the same author, is in a forward condition and ought to be published at an early date. All the plates illustrating the same are completed and the manuscript is ready for the press.

Dr. Noetling has prepared several parts of a new Series XVI of the Palæontologia Indica to illustrate the fauna of Baluchistán and North-Western frontier, which await only the completion of the plates, to be issued.

Several memoirs are in course of publication; part 1 of Vol. XXVII on "Marine fossils from the Miocene of Upper Burma" by Dr. Noetling has been published, and part 2 is in the press.

Gondwanas in South America.

A discovery of vast interest to Indian Geologists has been made during the year to which I must allude here; it is the discovery of a Gondwana flora[1] in coal-bearing deposits in Argentina, made by Dr. Kurtz, Professor at the University of Cordoba. The flora, with several species identical with such out of the Indian Gondwanas, occurs in beds, which overlie,—though in what manner is not known yet,—a series of beds containing a true carboniferous (Culm) flora. But the most interesting fact is that in Argentina *Neuropteridium validum* is found in the same beds with *Lepidodendron*, as I am informed by Dr. Kurtz, who has promised to give me further and more concise particulars.

Museum and Laboratory.

Mr. Holland, the curator, was absent on privilege leave from March 12th to June 27th and later on duty at Naini Tal, from which he returned on 13th November, but he has since been engaged in arranging the rock and mineral collections belonging to the Department.

The collection of rocks now amounts to over 16,000 specimens and they have been registered and partially arranged. Satisfactory progress has been made also in the classification and description of the collection. The miscroscopic characters of about 500 specimens of the crystalline rocks have been worked out, which will enable Mr. Holland to form a preliminary sketch of the classification of this group, which, though so largely represented in India, has hitherto received little more than superficial attention in the field, when as in previous years, the specimens in the collection were found to be types new to petrology, or were found to offer important evidence concerning unsettled petrographical problems. Mr. Holland has taken the opportunity, where possible, of utilizing the college vacations for the purpose of tracing out their field relations, and of collecting fresh material for confirming or correcting the microscopic work in the laboratory. As a result of work of this nature, the examination of the field relations of the new types of

[1] Records, Vol. XXVIII, p. 111.

peridotites discovered by Mr. Holland and referred to in my last annual report has enabled him, in conjunction with Dr. Saise, to completely describe them and to revise a map showing the nature and distribution of the intrusive rocks in, and the crystalline series around, the coal-field of Giridih.[1]

The interesting forms of metamorphism displayed by the crystalline rocks around this coal-field having been found to result in the production of garnets in pyroxenic type, the remaining pyroxenic rocks of India, and specially those of the Madras Presidency, whose presence and wide distribution in Southern India were first noticed by Mr. Holland in 1892, have been examined with special reference to the origin of this mineral which is so remarkably abundant in this country. In a paper contributed to the current number of the Records Mr. Holland has traced out the development of the garnets in these pyroxenic rocks, and, from the evidence obtained from widely separated areas in India, he concludes that the reaction-borders often confused with Kelyphite, and occurring so frequently associated with the garnets of pyroxenic rocks, represent a stage in the development, and not, as has generally been supposed, in the destruction of garnets. Mr. Holland has contributed another paper to the same number of the Records in which he has from the evidence of the specimens collected by himself in Madras combated the views expressed by Mr. Lacroix concerning the nature of the acicular inclusions giving rise to the phenomena of asterism, so frequently characteristic of Indian gem-garnets.

Amongst the specimens of interest added during the year are eight new meteorites.

Mr. Holland reports most satisfactorily on the work done during the year in the laboratory and museum by his assistant, Mr. T. R. Blyth.

Library.

The additions to the library during the past year amount to 1,949 volumes, of which 1,149 were acquired by presentation and 800 by purchase.

C. L. GRIESBACH.

Director, Geological Survey of India.

CALCUTTA,

The 31st January 1895.

[1] Records, XXVIII. p 121.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1895.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—Adirondack Survey.
„ New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—Johns Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Kon. Natuur Kundige Vereeniging in Nederl.—Indie.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
„ K. Preuss. Acad. der Wissenschaften.
„ K. Preuss Geologische Landesanstalt.
BOLOGNA.—Reale Accademia delle Scienze dell' Istituto.
BOMBAY.—Meteorological Department, Government of Bombay.
„ Natural History Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australia.
„ Royal Society of Queensland.
BRUSSELS.—Academie Royale des Sciences.
„ Société Belge de Geographie.
„ Société Belge de Geologie de Paleontologie et d' Hydrolog.
BUDAPEST.—Kön. Ungarische Geologische Anstalt.
„ Ungarische National-Museum.
BUENOS AIRES.—Acad. National de Ciencias en Cordoba (Republica Argentina).
BUFFALO.—Society of Natural Sciences.
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
„ Asiatic Society of Bengal.
„ Calcutta University.
„ Editor, The Indian and Eastern Engineer.
„ Meteorological Department, Government of India.
„ Survey of India.
CAMBRIDGE.—Philosophical Society.
„ University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CANADA.—Hamilton Association.
CHRISTIANA.—Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Academie Royale des Sciences.
„ Kong. Danske Videnskabernes Selskab.
DEHRA DUN.—Great Trigonometrical Survey.

DES MOINES.—Iowa Geological Survey.
DIJON.—Academie des Sciences, Arts et Belles-Lettres.
DRESDEN.—Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
EDINBURGH.—Geological Society.
" Royal Scottish Geographical Society.
" Royal Scottish Society of Arts.
FREIBURG.—Naturforschende Gesellschaft.
GENEVA.—Société de Physique.
GLASGOW.—Glasgow University.
GOTHA.—Editor, Petermann's Geographische Mittheilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALLE.—Naturforschende Gesellschaft.
" Academia Cæsarea Leop.-Carol. Naturæ Curiosorum.
KÖNIGSBERG.—Physikalisch-Okonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LIÈGE.—Société Géol. de Belgique.
LILLE.—Société Géologique du Nord.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—Iron and Steel Institute.
" Linnean Society of London.
" Royal Geographical Society.
" Royal Institute of Great Britain.
" Royal Society.
" Society of Arts.
" Zoölogical Society.
MADRID.—Reale Academia de Ciencias.
" Sociedad Geografica de Madrid.
MANCHESTER.—Geological Society.
" Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
" Royal Society of Victoria.
MILAN.—Societá Italiana di Scienzé Naturali.
MOSCOW.—Société Imp. des Natur.
MUNICH.—Kon. Bayerische Acad. der Wissens.
NAPLES.—Reale Academia delle Science Fisiche e Matematiche.
NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
" Editor, American Journal of Science.
NEW YORK.—Academy of Sciences.
OTTAWA.—Geölogical and Natural History Survey of Canada.
" Royal Society.
OXFORD.—University Museum.
PARIS.—Department of Mines.
" Editor, Annuaire Géologique Universel.

PARIS.—Ministere des Travaux Publics.
„ Museum d' Histoire Naturelle.
„ Société de Géographie.
„ Société Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Scienze.
„ „ Comitato Geologico d' Italia.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Académie Imperiale des Sciences.
„ Comité Géologique.
„ Russische Kaiserliche Mineralogische Gesellscha
SALEM.—American Association for the Advancement of Sc
SAN FRANCISCO.—California Academy of Sciences.
S. PAULO.—Commissao Geographica e Geologica.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—Kongliga Svenska Vetenskaps Akadémie.
SYDNEY.—Australian Museum.
„ Department of Mines and Agriculture, New South Wales.
„ Geological Survey of New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TOKIO.—Deutsche Gesellschaft für Natur und Volkerkunde.
TURIN.—Osservatorio della R. Universita di Torino.
„ Reale Accad. delle Scienze di Torino.
UPSALA.—Upsala University.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissens.
„ K. K. Geographische Gesellschaft.
„ K. K. Geologische Reichsanstalt.
„ K. K. Naturhistorisches Hof-Museum.
WASHINGTON.—Smithsonian Institution.
„ United States Department of Agriculture.
„ „ „ Geological Survey.
„ „ „ Mint.
WELLINGTON.—Mining Department, New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.

ZÜRICH.—Naturforschende Gesellschaft.

The Governments of Bengal, Bombay, India, Madras, N.-W. Provinces and Oudh, and the Punjab.

The Chief Commissioners of Assam, Burma, and the Central Provinces.

The Resident, Mysore.

On the Acicular inclusions in Indian Garnets. By THOMAS H. HOLLAND, A. R. C. S., F. G. S., *Deputy Superintendent, Geological Survey of India.*

I. INTRODUCTION.

1. In his detailed description of the rocks collected in 1819 by Leschenault de la Tour in the South of India, M. A. Lacroix has figured and described, in a basic pyroxenic gneiss, garnets containing acicular inclusions which he considers, from their high, positive, double refraction and straight extinction, to be rutile.[1] To the arrangement of these inclusions in systems mutually intersecting at angles of 60° M. Lacroix ascribes the asterism so frequently exhibited by Indian garnets.

2. During my work in South India I have found at various places in the Madras Presidency garnets in pyroxenic rocks of all degrees of acidity from granites to pyroxenites. In the smaller masses which rise above the plains at Pallavaram near Madras, at Mailam in South Arcot district, at Wallavanad in Travancore and in the Madura district the garnets, as well as the associated constituents of the rocks, are often free of these inclusions, but the rocks in the Nilgiri hills, which attain heights of 8,000 feet, and in the Shevaroys of Salem district are crowded with minute hair-like inclusions which appear in the quartz, felspar and garnet alike, whilst the pyroxenes, which are constant constituents throughout the whole series of these rocks, are schillerized with plates and rods like those in the well-known hypersthene of Paul's Island.

3. The occurrence of these hair-like inclusions in an isotropic mineral like garnet affords special facilities for the investigation of their optical properties. Whilst their characters agree in so many respects with those described by Lacroix, I find that instead of being referable to a uniaxial mineral like rutile they exhibit unmistakeable characters of a mineral crystallizing in the monoclinic system, and thus, whilst exhibiting in some sections extinction parallel to the long axis of the needles (orthopinacoidal sections), in other cases (clinopinacoidal sections) extinction angles as wide as 39° have frequently been measured.

II. CRYSTALLOGRAPHIC DISPOSITION OF THE NEEDLES.

4. The disposition of these needles with reference to the crystallographic orientation of their host, the garnet, is of an extremely interesting nature. Not only are the needles arranged with a constant relation between the direction of their long axes and the forms of the cubic system in which the garnet crystallizes, but the plane of symmetry, and consequently the orthopinacoidal plane, of each minute needle are arranged in definite crystallographic positions within the garnet—a circumstance quite in agreement with the definite crystallographic disposition of the products of schillerization in felspars, pyroxenes, olivines and other minerals which have been described on several occasions by Professor Judd. I regard these needles in the garnet, and what are probably the same things in the associated felspars, pyroxenes and quartz, as secondary in origin and belonging to the same

[1] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 311, and *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 176.

class as the inclusions which according to Professor Judd are the cause of the phenomena of schillerization.

5. Besides the sections in which the acicular inclusions appear to intersect one another at various angles I have found some which can be arranged in three distinct classes, and in which the disposition of the needles is capable of a very simple crystallographic explanation.

If we assume the long axes of the inclusions to be parallel to the long diagonal of the rhombus forming the face of the rhombic dodecahedron—the form in which the garnet crystallizes—or, which is the same thing, parallel to the solid edges of the octahedron, we obtain definite intersections exhibited in sections cut parallel to the octahedron, the cube and the rhombic dodecahedron respectively as follows:—

(1) In sections parallel to the *octahedron* there are three sets of needles lying in the plane of section and intersecting one another at angles of 60° (system *a*).

(2) Sections parallel to the *cube* exhibit two sets of needles lying in the plane of section and crossing one another at right angles (system *b*). Two other sets (system *c*) lying apparently at 45° to those belonging to system *b* will be seen, when examined with high powers, to be lying oblique to the plane of section, and consequently will as a rule appear to be shorter than those of system *b*, their maximum length in fact can never exceed

$$\sqrt{2} \times \textit{thickness of section.}$$

(3) Sections parallel to the *rhombic dodecahedron* display two systems of inclusions. One system (system *d*) lies in the plane of section and is crossed by a second system (system *e*) at an apparent angle whose tangent is $\sqrt{2}$, that is 54°16′. The two sets of system *e* consequently intersect one another at angles of $2 \times (90° - 54°16') = 71° 28'$, and its supplement.

III. OPTICAL ORIENTATION OF THE NEEDLES.

6. As the needles are monoclinic in crystallization and their lateral as well as vertical axes have a constant crystallographic disposition within their host the garnet, the optical characters exhibited by these three classes of sections are also different, and, assuming the long axis of each needle to be its vertical crystallographic axis, the positions of the orthodiagonal *axis* and the clinopinacoidal *plane* are easily determined.

(1) Sections of garnet cut parallel to the face of the cube and examined between crossed Nicols show system *b* lying in the plane of section and exhibiting an extinction angle as great as 39°. System *c*, however, apparently intersecting these at an angle of 45°, and seen by high powers to be lying oblique to the plane of section, exhibit straight extinction. Taking the plane of symmetry to be the optic axial plane, as is usual in monoclinic minerals, this plane must be parallel to the cube faces and exhibit the maximum extinction angle.

(2) In sections parallel to the octahedron all the needles (which have been referred to as system *a*) are cut obliquely to the plane of symmetry, and the extinction angle is consequently somewhere between zero and the maximum. Numerous measurements made on these sections gave results varying between 18° and 25°.

(3) Sections parallel to the rhombic dodecahedron give straight extinctions for system *d*, and oblique extinctions less than the maximum for system *e*.

7. The monoclinic acicular inclusions in the garnets are thus arranged as follows:—

Vertical axis of the needle parallel to the *edge of the octahedron* of the garnet.

Orthopinacoid parallel to the *rhombic dodecahedron*.

Clinopinacoid parallel to the *cube*.

That is to say, they are arranged with their orthopinacoidal faces lying on the cleavage planes of the garnet and with their long (vertical) axes parallel to the long diagonal of the rhombus. I am indebted to my colleague Mr. H. H. Hayden for having verified each of these conclusions in thin sections of garnetiferous pyroxenic rocks collected by myself at Nagaramalai, near Salem, and at Coonoor in the Nilgiri Hills.

8. Diller has described what appear to be similar inclusions in the garnets of a loose fragment of granulite found near the peridotite of Elliott County, Kentucky. According to Diller these inclusions are arranged at angles of 45° to one another, and are distinctly monoclinic with a maximum extinction angle of 30°.[1] If my conclusions are correct these inclusions should correspond to the two systems of needles *b* and *c* which I have recognised in sections cut parallel to the face of the cube (para. 5).

9. Lacroix states that the needles which he found in the garnets of the Salem pyroxenic gneiss show the positive double refraction of rutile. I find on examination of the monoclinic needles in my own specimens with a quartz-wedge that the axis of minimum optical elasticity $\mathfrak{c}$ lies at 39° to the vertical crystallographic axis *c*; there would therefore be an appearance of thickening on placing a quartz wedge with its axis parallel to an orthopinacoidal section. The straight extinction of such a section and its behaviour under the quartz-wedge would thus agree precisely with the characters of a uniaxial positive mineral like rutile; but that the mineral which forms these needles is biaxial is demonstrated beyond all possible question by the very wide extinction-angle and by the cross-sections which, although mere points, show strong double refraction.

10. I have, however, found needles of a mineral which show the straight extinction and strong, positive, double refraction of rutile in the augite-diorite forming the main mass of Parasnath in Bengal. But these are invariably shorter and form clusters in the centre of the garnet without displaying any recognisable regularity of crystallographic disposition within their host. Even in the same section they are not likely to be mistaken for the monoclinic needles that characterise the garnets in the Madras pyroxenic rocks.

11. According to Lacroix in hexagonal sections of these garnets the inclusions are arranged with parallelism to the sides of the hexagon; but unfortunately the

[1] *Bull. U S. Geol. Surv.*, No. 38 (1887), p. 27.

figure given by him does not show the crystal outlines with sufficient clearness to illustrate this statement. Although as the result of my investigations, I should not expect this to be the case, I have never found a garnet in the Madras rocks exhibiting its proper crystalline outlines, and have consequently been unable to make a direct test of this statement.

12. Whilst it is not possible to determine with certainty the species of mineral which forms the inclusions under consideration, their optical characters, so far as they can be investigated, are suggestive of those of sphene, in which also the axis $\mathfrak{c}$ meets the vertical crystallographic axis c at about an angle of 39°, although of course it does not necessarily follow that the vertical axis in this mineral would follow the direction of greatest elongation. A chemical test, however, made by Mr. Hayden and myself showed that the garnets contain small though unmistakeable traces of titanium.

13. The quartz and felspar which accompany the garnet, or occur in the associated pyroxenic rocks in the Nilgiri and Shevaroy hill-masses, are often crowded with fine hairs of a nature presumably similar to those occurring in the garnets. There seems little doubt that the blue colour of the quartz and the moonstone opalescene, which so frequently characterises the felspar of the more coarsely-grained charnockites, are due to the presence of these inclusions, whose definite crystallographic disposal suggests their secondary origin in common with the ordinary products of schillerization.

14. It is not without interest that in garnets with striated faces the striations are parallel to the longer diagonal of the rhomb faces, which I have shown to be the position of the hair-like inclusions, and according to Descloizeaux asterism has generally been observed in garnets having such striated faces. There seems little doubt, as Lacroix suggests, that the asterism exhibited by some Indian garnets is due to the fine hair-like inclusions which exhibit such a perfectly symmetrical disposition not only of the long axes but also of the lateral axes of crystals so minute that their cross-sections, even with high powers, appear as mere points of light in the isotropic ground-mass of their host the garnet. I can recollect no prettier illustration of Professor Judd's generalization concerning the secondary changes brought about by agents of statical metamorphism acting on the minerals of deep-seated rocks and giving rise to the phenomena which he has described under the name of schillerization.

CONCLUSION.

15. The hair-like inclusions which give rise to the phenomena of asterism in Indian garnets are not rutile as stated by Lacroix, but are monoclinic in crystallization, exhibit a high double refraction and show an extinction angle as wide as 39° ($\mathfrak{c} \wedge c$) to the long axes of the needles. They are arranged with remarkable regularity of crystallographic disposition within their host the garnet, having their long axes parallel to the edge of the octahedron, their orthopinacoidal faces parallel to the face of the rhombic dodecahedron and their clinopinacoids parallel to the cube. They are considered to be secondary in origin along with the similar hair-like inclusions which give rise to the phenomena of schillerization in the associated blue quartz, moonstone and hypersthene of the pyroxenic rocks in which the garnets occur.

On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks, by THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With plate 1.)

CONTENTS.

A. THE ORIGIN AND GROWTH OF GARNETS.

I.—INTRODUCTION.

1. Garnets occur in rocks of every degree of acidity from granites to peridotites, and the ordinary iron-alumina garnet is well-known as one of the commonest amongst the products of the contact-metamorphism of aluminous rocks. Whilst its secondary origin can be so easily proved in the slates and schists which have been changed by proximity to igneous intrusions, the origin of garnet when a constituent of igneous rocks and of the crystalline types generally cannot always be so satisfactorily determined. As a rule, it is impossible to settle from the rock specimen *per se* whether the garnet is a primary or a secondary constituent; but from its more frequent occurrence in the gneissose crystallines than in rocks of massive habit, it is more generally grouped—though seldom with better reason than analogy—amongst the constituents of secondary origin.

2. The very prevalent occurrence of garnets amongst the pyroxenic granulites of South India, to which I have paid considerable attention during the last four years, has led me to make a more widely extended investigation amongst the garnetiferous rocks of this country with a view to obtaining more exact evidence concerning the origin of this mineral. I have considered this investigation the more necessary on account of the fact that Dr. J. Lehmann, in his classical work *Die Entstehung der altkrystallinischen Schiefergesteine*, has recorded the frequent

occurrence of garnet in the pyroxene-granulites of Saxony, which appear in many respects to closely resemble the Madras series But whereas Dr. Lehmann considers the garnet, where it is surrounded with reaction-borders resembling Schrauf's kelyphite, to be passing into pyroxene, I have been led to a totally different conclusion with regard to the pyroxenic rocks which I have studied in India, and in which reaction-borders, apparently quite similar in character, are frequently found between the pyroxene and garnet. These, it seems to me, afford, so far as the Indian rocks are concerned, most decisive evidence in favour of regarding the garnets as secondary in origin and derived from the pyroxene which was amongst the original constituents of the rock.

3. That this conclusion is capable of wider application cannot of course be claimed, but it seems to me that in many cases where reaction-borders around garnets have been described, the precise evidence concerning the *direction* of the change might have been studied with advantage. The mere fact that the proportionate area of garnet core and reaction-border varies from cases in which the border is proportionately narrow to those in which the garnet forms merely a small nucleus, or even totally disappears, is no proof whatever that the reaction-border is formed at the expense of the garnet. As the garnets are most irregular in shape every one of these stages might be obtained by sections through the centre, near the surface, or along a flat face of the crystal which is so surrounded by a reaction-zone.

4. It should also be understood that these conclusions have no bearing whatever on previously-stated views concerning the nature of the *kelyphite* rims which surround the pyropes described in many peridotites, nor has it necessarily any connection with the evidence obtained from the Saxon pyroxenic rocks; but as I find it necessary to consider the garnets of secondary origin in all the pyroxenic rocks which I have so far studied in India, it may be advisable to state in detail the steps by which I have been led to this conclusion, the more so because the processes by which pyroxenes are converted into garnets seem to have been described, so far as I can find, in one case only. Brauns in 1888 described the formation of a lime-iron garnet in the palæopicrite of Bottenhorn as an alteration form of augite in which chemical analysis indicated a removal of alumina.[1] Beside this the literature at my disposal in Calcutta has not revealed a single case of a garnet formed from pyroxene, although the contrary has been asserted in more than one instance.

5 The evidence obtained from the same material also offers a very simple explanation of the origin of the *micropegmatitic intergrowths* of garnet with such white minerals as quartz and felspar. The micropegmatitic structure is consequently in these instances considered to be of secondary origin.

II.—THE REACTION-BORDERS OF GARNETS.

6. The fibrous zones which surround the pyrope in olivine-rocks were first described by Schrauf as a primary constituent of pyrogenic origin to which he gave the name *kelyphite*,[2] but von Lasaulx showed that these borders are in some cases,

[1] *Zeitschr. d. d. geol. Ges.*, Vol. XL (1888), p. 475.

[2] *Zeitschr. f. Kryst.*, Vol. VI (1882), pp. 333 and 358; also *Neues Jahrb. f. Min.*, 1884 (II), p. 21.

mixtures of different minerals, generally members of the pyroxene-amphibole group and of secondary origin.[1] Becke found similar borders around the garnet of Steineck composed of picotite and several members of the pyroxene-amphibole group.[2] Diller found the pyropes in the Elliott County peridotite composed largely of biotite,[3] whilst von Camerlander described in the granulites of Prachatitz a micropegmatitic intergrowth of augite and plagioclase forming a border around garnet.[4]

7. Seeing kelyphite has been found to be a mixture of minerals so variable in composition, and especially as in all cases described it has been regarded as a product of the *destruction* of garnet by reaction with olivine or pyroxene, either during or subsequent to consolidation, I shall avoid altogether the use of the term in connection with the fibrous zones which surround the garnets in the cases about to be described, for these I consider to represent the products not of destruction but a stage in the *development* of the garnets with which they are associated. They will be referred to therefore merely as *reaction-borders.*

8. Lacroix has described radiate zones composed of micropegmatitic intergrowths of hornblende and felspar around garnets in an eclogite from Gerscao-en-Plounevez, Finisterre.[5] He has also figured and described a radiate fringe around garnets in a pyroxenic rock from the Salem district,[6] but has offered no explanation of the origin of the phenomena in these cases.

9. The reaction-borders measure about ·04 mm. across and are composed of two distinct layers, an inner (garnet side) layer of colourless mineral in which clavulate and vermiform pieces of a pale green actinolite are arranged approximately perpendicular to the garnet surface, giving with the low powers an appearance of radiate fibrous structure. The colourless mineral with crossed nicols shows colours about equal to those of the felspars in the same sections, and display lamellar twinning bands. The outer zone consists of a narrow band of magnetite-granules forming a margin to the pyroxene.

III.—THE ROCKS IN WHICH THE GARNETS OCCUR.

10. The specimens which it is proposed to select as examples for the study of the origin and growth of garnets have been obtained in two principal areas separated from one another by distances of at least 700 miles.

The first group of rocks occurs as large dykes and bosses of diorites amongst the gneisses and schists of Chota Nagpore and the Sonthal Pergunnahs in Bengal. These rocks by their resistance to agents of denudation are conspicuous as hummocks and even high hills in the neighbourhood of our coal-fields. As they can often be traced up to the boundary faults, but are never intruded into the stratified rocks of Lower Gondwana age within the field, it is presumed that they are older than the deposits of that system. In nearly all cases which I have examined, these can be shown to have been derived from original pyroxene-plagioclase rocks, which show

[1] *Sitzungsber. der Niederrhein. Ges. f. Natur und Heilkunde*, 3rd July, 1882.
[2] *Tschermak's min. u. petr. Mitt.*, Vol. IV (1882), p. 324.
[3] *Bull. U. S. Geol. Survey*, No. 38 (1887), p. 15.
[4] *Jahrb. d. k. k. geol. Reichsanstalt*, Vol. XXXVII (1887), p. 133.
[5] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 142.
[6] *Ibid.*, p. 322; also *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 183.

a strong family likeness in the field and apparently belong to a petrographical province of pre-Gondwana age. A closer examination reveals some very interesting differences in the changes which they have suffered by the various agents of metamorphism.

The dynamical metamorphism to which some of these rocks have been subjected has resulted in the production of well-foliated epidiorites and hornblende-schists. In others, where earth-movements have been preceded by the production of sodic chloride inclusions along the twin-planes of the felspar, scapolite is conspicuous amongst the new minerals;[1] but those in which garnets have developed show slighter, though decided, signs only of deformation by dynamical agencies. To this last mentioned group belong some dykes at Mongrodih near Giridih, some rocks collected by the late Mr. Fedden in the Ijri valley of Manbhúm, and the main mass of Parasnath, a sacred hill rising to a height of 4,479 feet on the borders of the Hazaribagh and Manbhúm districts.

11. The second group of rocks forms the great hill-masses of the Madras Presidency——the Nilgiris, Shevaroys, Palnis, Anaimalais, Western Ghats and Cape Comorin. These rocks, although varying so widely in silica percentage from acid granites to pyroxenites and even peridotites, present a most remarkable and unmistakeable family likeness in the field.

Microscopic examination shows that without a single exception the unaltered forms are characterized by the presence of a rhombic pyroxene approaching hypersthene in composition, which may occur in very small proportions, as in charnockite, or may make up almost the entire rock, as in some pyroxenites. The hypersthene may be the sole representative of the group of ferro-magnesian silicates, or it may be accompanied by augite, hornblende, biotite, graphite and garnet. Sometimes it is replaced entirely by garnet in rocks which I hope to show are beyond question altered forms of the pyroxenic series.

IV.—EVIDENCES OF THE GROWTH OF GARNET.

12. The special features in the structure of these rocks which appear to corroborate one another in the evidence they offer in favour of the growth of garnet at the expense of the pyroxenic constituent, may be considered under the following heads:—

(1) Limitation of the reaction-borders.
(2) Uralitization (amphibolization) of the pyroxenes near the garnets.
(3) Schillerization of the pyroxenes.
(4) Parallel growth of adjacent garnet crystals.
(5) Field relations of the pyroxenic and garnetiferous rocks.
(6) Chemical changes involved in the formation of garnet.

1. Limitation of the Reaction-borders.

13. The reaction-border appears wherever the garnet meets the pyroxene or, more strictly speaking, its paramorph hornblende, but there is not a trace of it where the garnet comes in contact with felspar or quartz. This of course only shows that there is some kind of reaction between the garnet and the pyroxene;

[1] See Holland and Saise. "On the Igneous Rocks of the Giridih (Kurhurbaree) Coal-field and their Contact Effects" *Rec. Geol. Surv. Ind.*, Vol. XXVIII (1895), p. 121.

but the fact that opposite the pyroxene the garnet bulges out to meet the latter is a circumstance which would naturally be expected if we regard the pyroxene as the source of the garnet material.

Fig. 1 illustrates a case in which the garnet, fringed by a reaction-border, bellies out in this manner opposite the pyroxene, whilst colourless felspar fills a bay in the garnet, which at this point is without a reaction-border. This case will be referred to again in describing the origin of the micropegmatitic intergrowth of garnet and felspar.

2. *Uralitization (Amphibolization) of the Pyroxenes near the Garnets.*

14. The formation of these reaction-borders between the garnet and pyroxenes seems to be always accompanied by the formation of hornblende, which lies between the unaltered augite and the reaction-zone, and which seems to be a preliminary change in the augite necessary to the development of the garnet. In parts of the rock free of garnets the augites show the characteristic signs of incipient uralitization in the form of green pleochroic patches. This conclusion is further supported by the fact that occasionally pale green augites, which do not show the slightest sign of amphibolization, abut against the garnet without a trace of a reaction-border.

If the opposite change—that is the formation of pyroxene from garnet—were in progress, we should have in this instance a case of the formation of hornblende from garnet followed by the transformation of the former mineral into augite—a change under the circumstances quite contrary to experience. The alteration of the pyroxene near the garnets is only an advanced stage of that which is seen to be commencing in nearly all the augites and is a case of ordinary amphibolization. That such is the real direction of change is even more clearly demonstrated by the next point of evidence.

(3) *Schillerization of the Pyroxenes.*

15. The original augite, in the rocks for instance from Parasnath and the Ijri valley, are darkened, often almost blackened, with minute rods and plates regularly arranged as in diallage and forming an ordinary example of schillerization, whilst the hornblende, which has been derived from this augite, is free of such inclusions. The schillerization of the ferromagnesian constituent must, therefore, have occurred before its amphibolization, and as the amphibolization appears to be a constant accompaniment of, and probably an essential preliminary to, the development of the garnet, the schillerization must have occurred also before the formation of the latter mineral. If the opposite change had occurred we should have a case of the transformation of garnet into a clear green hornblende, followed by the change of green hornblende into schillerized augite. In view of Professor Judd's explanation of the phenomena of schillerization such an alternative explanation of the facts may be safely rejected without further discussion. There is no doubt that the amphibolization of the schillerized augite is accompanied by the absorption of the secondary ferruginous products, the iron of which enters into the composition of the hornblende, and then of the final product, garnet.

The relative positions of the minerals in the rock are thus—

Schillerized Augite.	*Clear green Hornblende.*	*Reaction border.*	*Garnet.*

$\longrightarrow$

(4) *Parallel growth of adjacent Garnet-crystals.*

16. In the Manbhúm rocks the large garnets are clear and pink in their centres, but towards the margin, where they approach the ferromagnesian mineral, numerous vermiform, radially-arranged cavities destroy the transparency of their selvages. Beyond—that is, outside—these zones of cavities the crystal-outlines of the garnet can be traced, and these by repeated alternation of forms give rise to saw-like outlines like those which characterize a section of "Babel" quartz. Beyond this crystal-outline there is a zone of felspar and vermiform actinolite which often penetrates the crystal limits and communicates with the vermiform cavities forming the zone immediately inside the faces of the garnets. It is evidently along this zone that the change is proceeding.

Here and there clusters of minute garnets are to be seen which offer equally instructive evidence. These are often so small that they are darkened throughout by the vermiform cavities and indeed in many cases are but imperfect rhombic dodecahedral clearings in the hornblendic material, but in which with the higher powers of the miscroscope it is not difficult to pick out the isotropic garnet from the imperfectly cleared dirt and cavities. From this stage, as the clear central area enlarges and shows the garnet pink colour, we can trace every gradation up to the largest crystals in which this selvage only covers a small fraction of the total area of the section. It is clear that as growth proceeds the proximal ends of the vermiform cavities are gradually obliterated by deposition of garnet substance in crystallographic continuity with the skeleton, and so the central area grows simultaneously with the extension of the crystal borders amongst the hornblendic material around.

Wherever the garnet comes into contact with felspar instead of a ferro-magnesian mineral, there is no such development of crystal-form nor is there a zone of vermiform cavities: the clear pink garnet is simply moulded on to the older felspar. It is only opposite the pyroxene—that is where growth can proceed without interruption—that the crystal-outlines occur. If the reaction-zones represented decom position of the garnet we should naturally expect irregular corrosion of the crystal, whereas we have well-shaped crystals and this only where the reaction-borders occur.

Wherever patches of small young garnets are found growing around isolated centres, it is frequently found that several of them may develope with crystallographic parallelism and on meeting form one large crystal. This interesting occurrence is more strikingly exemplified by patches of small crystals which form in the neighbourhood of a large one with their faces parallel to those of the large crystal and consequently to one another (Fig. 3).

17. The parallel growth of these minute crystals around the larger and probably older individuals forms a very pretty illustration of the influence a crystal exerts beyond the limits of its own faces. In a case where free movement of the material is possible, as in molten material, the surrounding magma is impoverished by removal of the crystallizing substance, and in this way we get in the tachylytes a clear zone of glass around each magnetite-crystal, whilst beyond this zone the glass is darkened by magnetite-dust. The pink film around the growing cobalt-chloride crystals in a blue solution of the salt forms a still more striking illustration of what O. Lehmann calls *der Hof des Krystalles.*[1]

When crystal-growth takes place *after* the consolidation of the substance and as

[1] *Zeitschr. f. Kryst.*, Vol. I, p. 99.

a secondary change, the "sphere" of the crystal influence is indicated, as might be expected, not by removal of material, but by parallel development from isolated centres confined to fairly well-defined limits around the central crystal, as exemplified by the beautiful instances of garnets in the Manbhúm pyroxenic rock.

18. The growth of garnets in these pyroxenic rocks which show no signs of exposure to extreme temperatures since their primary consolidation, is comparable to the well-known secondary enlargements of such minerals as hornblende (Becke, Van Hise, Harker, Bonney), augite (Van Hise, Merrill), plagioclase-felspar (Judd) and orthoclase (Haworth, Holland).

(5) *Field relations of the Pyroxenic and Garnetiferous rocks.*

19. One of the most interesting types of the South Indian pyroxenic rocks is a granite composed essentially of quartz, orthoclase largely in the form of microcline, hypersthene, and always considerable quantities of opaque iron-oxides. This rock which possesses a striking individuality both in the field and under the microscope, I have described elsewhere under the name of *charnockite*.[1] As a rule it is compact and brittle with a very characteristic dark grey or green clour; but near its junctions with the norite, with which it is always associated, it changes very rapidly, almost suddenly, to a dirty white colour, becomes granular in structure, crushes easily under the hammer, shows a slight but distinct foliation, and is seen then to be sprinkled with garnets.

Under the microscope these changes in macroscopic characters are seen to be accompanied by corresponding changes in microscopic structure. Instead of the perfect granitic structure which characterises the unaltered rock, the weaker minerals are seen to be crushed and surrounded with selvages of mylonite, whilst the quartz-crystals show very marked "undulose" extinctions which invariably characterise rocks subjected to pressure.

But that this is an altered form of charnockite there would be little doubt even if the fact could not be demonstrated beyond question in the field. The quartz, microcline and black iron-ores are recognisable in precisely the same propoitions, but instead of hypersthene there are irregularly-shaped, pink garnets, which bear to the rest of the rock a proportion, so far as determinable by sections, identical with that of the original hypersthene. That the garnets in this case have been formed from the hypersthene as one among the unmistakeable results of the metamorphism of charnockite there can be no question. Examples of this kind are most beautifully illustrated in the low hills immediately east of the railway station at Pallavaram near Madras, and at Coonoor in the Nilgiri hills.

Simultaneous with the appearance of a granulitic structure and other signs of pressure, the hypersthene has given place to pink garnet. A similar association has been recorded by Mr. Teall in the gneissose granite of Beinn Vuroch, where the ordinary granite differs from the gneissose forms in the presence of garnet accompanied by a granulitic structure in the latter varieties.[2]

I have recently traced up a dyke near Kidgeree, in the Hazaribágh district, from a compact pyroxenic type to a foliated garnetiferous one in which the pyroxene has completely disappeared.

[1] *Journ. As. Soc. Beng.*, Vol. LXII (1893), p. 162.
[2] Brit. Petrography (1888), p. 326.

6. *Chemical changes involved in the formation of Garnet.*

20. It would of course be extremely interesting to trace the precise chemical changes which accompany the transformation of pyroxene into garnet; but the latter mineral is so intergrown with felspar and crowded with inclusions that separation of sufficient clean material for chemical analysis was found to be impracticable.

21. There is no doubt, however, that the change is not a simple paramorphic one. The garnet contains less silica and probably a smaller proportion of lime and alumina than the pyroxene from which it is derived. The excess of silica combines with the alumina, lime and small quantities of alkalies present in the pyroxene to form the plagioclase felspar which is so frequently intergrown in a pegmatoidal manner with the garnet. The chemical constituents of the pyroxene are thus re-arranged to form two minerals—one more basic and the other more siliceous than the original. As the more garnetiferous portions of the slides invariably contain more felspar than the portions where the pyroxene has suffered no change, the microscopic evidence confirms this conclusion.

22. Another microscopic character which has a direct bearing on the chemical question is the depth of colour of the garnets. In the Madras rocks the colour of the pink garnet is most strikingly similar to the pink of the highly pleochroic hypersthenes in the same slide, so much so that without moving the polariser sections of the latter mineral might very easily be mistaken for garnets. In some quartz-biotite-norites from Isa Pallavaram, near Madras, the iron seems to have been principally used up by the biotite, whilst the rhombic pyroxene and the associated garnet too are almost colourless. The more basic rocks, approaching pyroxenites in composition, from Nagaramalai, in the Salem district, contain, on the other hand, highly-pleochroic hypersthenes with deep pink or even red garnets. Some of the rocks of the Nilgiris also contain deeply-coloured garnets associated with highly pleochroic rhombic pyroxenes that approach amblystegite in composition. As the pink colour of the garnets and the intense pleochroism of hypersthenes are dependent, though not in direct proportion of course, on the percentage of iron present, this simultaneous increase of intensity of colour would naturally be expected.

23. The facts cited under this head do not prove the *direction* of the chemical changes which have taken place amongst the rock-constituents, but as they indicate a constant chemical relation between the pyroxene and the garnet in the same rock, they are so far in agreement with the previously-stated evidence.

B.—MICROPEGMATITIC INTERGROWTHS OF GARNET WITH OTHER MINERALS.

24. The structure produced by the intergrowth of quartz and felspar in graphic granite has, since its first description on a microscopic scale by Zirkel in 1871, been known under such names as micropegmatitic (Michel-Lévy), granophyric (Rosenbusch) and implication-structure (Zirkel), whilst special types of it are known as ocellar structure (Fischer), centric structure (Becke), and pseudo-spherolithic structure (Rosenbusch).

Although the most common example of these structures is produced by the intergrowth of quartz and felspar, other minerals are found mutually entangled in a precisely similar manner.

25. Becke has mentioned cases of a micropegmatitic intergrowth of garnet and felspar in augite gneiss,[1] and Lacroix has described and figured a similar intergrowth of garnet and quartz in one of the pyroxenic rocks of Ceylon.[2] Heddle has mentioned the occurrence of quartz-inclusions in garnet giving apparently a similar structure.[3]

26. The commonest examples of the structure, namely, those produced by the intergrowth of quartz and felspar, have generally been considered to have originated during the primary consolidation of the rock by simultaneous crystallization of quartz and felspar in the proportions of an eutectic mixture.[4]

27. But in 1883 Irving suggested the secondary origin of the quartz in the micropegmatitic structures of some granites and augite-syenites near Lake Superior.[5] Professor Judd showed the secondary origin of the quartz in similar structures and associated with the felspars of some Mull and Portsoy gabbros.[6] In 1889 the same author produced further evidence in support of his original conclusion and showed the connection between these structures and the secondary growth of minerals in igneous rocks after their consolidation.[7] Further examples of the same structure, considered to be connected with the secondary silicification of rocks, have been described by Miss Raisin in some nodular felstones of the Lleyn in Wales,[8] and by myself in some rhyolites from Korea.[9]

28. The pyroxenic rocks of Chota Nagpore, in which I have just described the growth of garnets, afford most striking cases of micropegmatitic intergrowths of garnet with plagioclase, and less often with quartz, about the secondary origin of which there seems to me little room for doubt. These intergrowths are moreover, as in the examples mentioned by Professor Judd, directly dependent on the enlargement of the minerals after the primary consolidation of the rocks (Fig. 4).

29. It has already been mentioned that numerous small garnets are found springing up in the vicinity of larger masses, sometimes isolated and sometimes in clusters. Now, wherever patches of these small garnets are found the isolated crystals grow, as already described, with crystallographic parallelism to one another (para. 16). The bearing of this fact on the origin of the micropegmatitic structure is obvious; the growth from isolated centres continues until the crystals, already in parallel groupings, meet and join as one, whilst the felspar, formed as a by-product in the decomposition of the pyroxene and growing at irregular intervals, becomes enveloped in a continuous framework of garnet.

30. It has already been remarked, too, that the so-called reaction-borders appear only between the garnet and the ferromagnesian constituent undergoing change, whilst the former mineral shows a very definite and simple outline where it

[1] *Tschermak's min. und petr. Mitth.*, Vol. IV. (1882), p. 406.

[2] *Bull. de la Soc. Min. de Fr.*, Vol. XII (1889), p. 317, and *Rec. Geol. Surv. Ind.*, Vol. XXIV (1891), p. 179.

[3] *Min. Mag.*, Vol. II (1878), p. 230.

[4] See Teall, Brit. Petrography (1888), p. 391.

[5] *U. S. Geol. Surv. Monograph* No. V, "The copper-bearing rocks of Lake Superior," p. 114.

[6] *Quart. Journ., Geol. Soc.*, Vol. XLII (1886), pp. 72 and 95.

[7] *Ibid.*, Vol. XLV (1889), p. 175.

[8] *Ibid.*, Vol. XLV (1889), p. 252.

[9] *Ibid.*, Vol. XLVII (1891), p. 177.

comes in contact with the felspar (para. 13). In this way growth occurs only opposite the ferromagnesian constituent, and the garnet bellies out in such areas, with the result that the bays and inlets are filled with felspar. A continuation of this process results in the complete envelopment of the felspar and its consequent appearance in section as isolated crystals. As might be expected, the crystal-outlines of the garnet are exhibited only when the pyroxene is sufficiently abundant to allow of free growth, whilst development is proportionately interrupted when such minerals as felspar and quartz are present in quantity. Both these processes are specially well illustrated in the garnetiferous rocks of Manbhúm and in the rocks of Parasnath.

31. Although a certain quantity of felspar and quartz occurs amongst the primary constituents of the Manbhúm and Parasnath rocks a larger quantity is formed as a by-product in the re-arrangement of the pyroxene-molecules. Hence it is that garnet is more frequently intergrown with felspar and quartz than with the more basic minerals. The minerals intergrown are thus produced simultaneously by secondary changes in a pyroxenic rock, and the average composition of the mixture of garnet and white mineral formed is approximately that of the original ferromagnesian silicate which has undergone the chemical re-arrangement of molecules.

V.—SUMMARY OF CONCLUSIONS.

32. The garnets occurring so abundantly in the pyroxenic rocks of India frequently exhibit fibrous reaction-borders generally composed of felspar, actinolite and sometimes magnetite, and display a radiate arrangement of the fibres similar to the structure characteristic of Schrauf's kelyphite.

33 The reaction-border occurs only between the garnet and a ferromagnesian silicate, never between garnet and felspar or quartz (para. 13).

34. The ferromagnesian silicate nearest the garnet is generally green actinolite which can be traced out in some cases (Manbhúm, Parasnath) to augite, and is evidently derived from the latter mineral by the ordinary process of amphibolization (para. 14).

35. The augite undergoing the paramorphic change into hornblende is darkened by the minute regularly-arranged inclusions which characterize diallage and present the ordinary phenomena of schillerization. The passage into hornblende is accompanied by the absorption of these dark ferruginous inclusions and clear green actinolite is the result (para. 15).

36. Where the rock is composed almost entirely of pyroxene changing to hornblende, the garnets develope with a regular crystalline outline, and several crystals developing in close proximity often exhibit crystallographic parallelism to one another. Where felspar and quartz occur in quantity as primary constituents, the garnet exhibits no crystal-outline, but is moulded on the white minerals, and the line of contact in such cases never shows a reaction-border (para. 16).

37. The garnets are frequently found bellying out opposite the pyroxenes, whilst felspar and quartz occupy the bays and inlets. A continuation of the growth of the garnet results in the gradual enclosure of such felspar and quartz crystals and their consequent appearance in section as isolated masses (para. 30).

38. The alteration of the original schillerized pyroxene is, therefore, not a simple paramorphic change, but is a decomposition which results in the simultaneous formation of a more basic mineral, garnet, and a more acid one, felspar.

39. The simultaneous development of these two minerals results in their micropegmatitic intergrowth. In the case of the felspar the similarity of optical orientation of isolated portions proves their crystallographic parallelism. In the case of the intergrown garnet the occurence of numerous small crystals developing around a larger central one exhibiting parallelism of crystal-outline with the larger central garnet and with one another, results in the ultimate formation of one large crystal of garnet, in which both original felspar and quartz, as well as the secondary felspar formed during the destruction of the pyroxene, become entangled to produce a micropegmatitic structure (paras. 29 and 31).

40. The micropegmatitic structure is thus considered to be of secondary origin as has recently been shown to be true for similar cases of the more common intergrowth of quartz and felspar.

41. The development of felspar as a by-product during the formation of garnet from pyroxene explains the more frequent record of micropegmatitic intergrowths of garnet with felspar than with any other mineral.

42. The reaction-border occurring around garnets may therefore represent a stage in the *development* of garnet from the products of the molecular disintegration of original ferromagnesian silicates, and does not always indicate the *destruction* of garnet as has generally been considered to be the case with kelyphite borders.

43. The evidence offered by the microscopic characters briefly indicated in the previous paragraphs is corroborated by the field relations of the pyroxenic and garnetiferous rocks. Compact pyroxenic rocks, with a perfect granitic structure, become friable and imperfectly foliated near their margins, where the pyroxene disappears, garnet, in about the same proportions, takes its place, and the rock becomes granulitic in structure (para. 19).

VI. EXPLANATION OF PLATE.

FIG. 1. Garnet crystal with reaction-border which only occurs between the garnet and the pyroxene, or, more strictly speaking, its paramorph hornblende. Along the bay, which is filled in with felspar, the outline of the garnet is a simple one without reaction-border. In this section the pyroxene, which is darkened by schillerization products, is amphibolized opposite the reaction-borders only, the portion abutting against the felspar being unaltered. In *pyroxene-diorite* from Parasnath, Bengal. Rock No. 9.-328. Slide No. 1154. Magnified by 43 diameters.

FIG. 2. Garnet crystals, large and small, developing in amphibole derived from pyroxene with crystallographic parallelism and showing reaction-borders. In *garnetiferous pyroxenite*, from the Ijri valley, Manbhum, Bengal. Rock No. 3·23. Slide No. 1376. Magnified by 25 diameters.

FIG. 3. Small garnets growing with crystallographic parallelism to a larger neighbour with reaction-borders. There are large numbers of such small crystals growing around the large one although beyond the limits of the field photographed. Slide No. 1976. Magnified by 43 diameters.

FIG. 4. Micropegmatitic intergrowth of garnet and felspar. The optical continuity of the isolated sections of the felspar is shown by parallel twin-bands when examined between crossed Nicols. Slide No. 1376. Magnified by 20 diameters.

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Fig 1

Fig 2

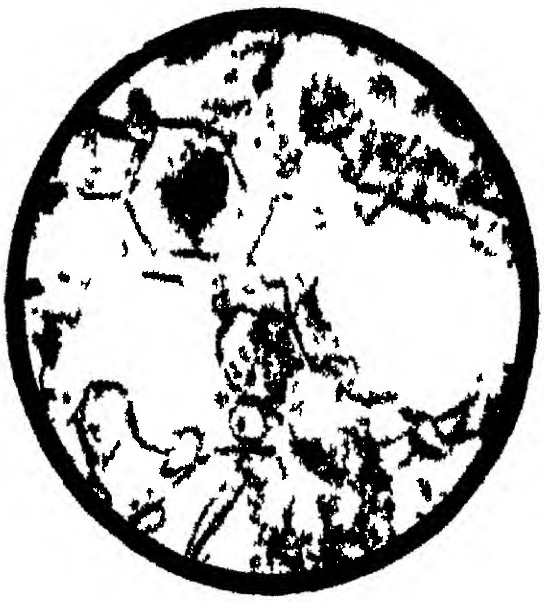

Fig 3

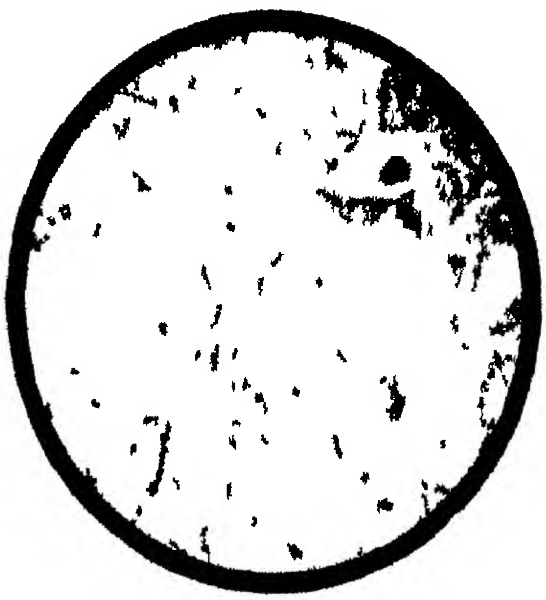

Fig 4

SECTIONS OF ROCKS SHOWING THE GROWTH OF GARNETS

Photographed by T. H. Holland

H. M. Hutchings — Survey of India Offices Calcutta February 1896

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1896. August.

On some Igneous Rocks *from the* Tochi Valley: *by* H. H. HAYDEN, B. E., *Assistant Superintendent, Geological Survey of India.*

The specimens about to be described form part of a collection made in Waziristan by Mr. Smith, of the Geological Survey of India. They are, to a great extent, derived from dykes and intrusions occurring among the tertiary beds of the Tochi Valley,[1] and represent a very fine series of varying texture and basicity, ranging from a compact and glassy prophyrite, through trachyte, basalt, dolerite and gabbro to serpentine and bronzitite.

They have all undergone a considerable amount of alteration, which is particularly noticeable in the gabbros, the felspar of which has in many cases become saussuritic, while the dolerites furnish examples of every stage in the conversion of augite into hornblende. Evidence of dynamo-metamorphic action, also, is abundant; the crushing and shearing of the serpentines, the foliation of some of the gabbros, with the brecciation of their constituent minerals, all bearing witness to the pressure to which these rocks have been subjected.

The specimens consist of two sets, *viz.*, (1) a series collected *in situ*, in the neighbourhood of the tertiary beds, and composed of igneous rocks, with baked and altered shales and fault-breccias, and (2) a number of specimens found in the bed of the Tochi river, being chiefly portions of rolled and waterworn pebbles of the above igneous rocks, with some mica-schist and altered limestone.

Serpentine.

Of the igneous rocks, the serpentines and gabbros are the most numerous, as well as the most varied in composition. As a rule, the serpentines are of a more or less uniform dark green colour; at times, however, they show spots of a translucent, very pale apple-green to greenish-white serpentine. Their hardness varies from $3\frac{1}{2}$ to $4\frac{1}{2}$, and their specific gravity from 2·49 to 2·76, this latter value being given by a specimen with many of the light spots already mentioned.

Microscopic characters. Serpentine.

Under the microscope, the serpentine is seen to vary considerably, some portions showing the mesh-structure characteristic of olivine, while others may be seen to have arisen from the alteration of pyroxene and amphibole. In some cases the rock has evidently undergone much pressure, the serpentine fibres being bent,

[1] See *Records, G. S. I.*, Vol. XXVIII., p. 109.

twisted and fringed at the ends, while in places they have been broken through and faulted, one part having been shifted past the other.

The serpentine varies from pale greenish-yellow to colourless, and is frequently intersected by clear bands of picrolite, which mineral may also be recognised on the outer surface of some of the hand-specimens.

Accessory minerals.

The chief accessory minerals found in these rocks include olivine, augite, enstatite, bastite, hornblende, and magnetite, the bastite at times occurring in large and brilliantly lustrous plates scattered throughout the rock. Several sections of an isotropic mineral, of a rich brown colour by transmitted light, represent chromite or picotite.

General characters.

The olivine is usually in an advanced stage of serpentinisation, being cracked and altered, while the cracks are filled with serpentine and dust-like magnetite. No. $\frac{10}{770}$. It has already been mentioned that one of the specimens has a higher specific gravity than the rest, *viz.*, 2·76. In the hand-specimen, the rock has a somewhat mottled appearance, consisting of a dark groundmass with large pale-green to greenish-white spots. The mineral of these spots is somewhat harder than the remainder of the rock, for it is found to scratch fluor spar, its hardness being therefore higher than degree 4.

Microscopic characters. Serpentine.

Under the microscope, the rock is seen to consist almost entirely of serpentine, of which the greater part has been derived from olivine; a considerable quantity, however, has arisen from the alteration of enstatite.

Enstatite.

Some unaltered enstatite still remains, one large crystal being especially noticeable, owing to the fact that it polarises in patches of blue and grey: this effect is evidently due to brecciation, the crystal affording evidence of having been broken up, for veins of serpentine run through it, while portions of the enstatite may be seen scattered, in the forms of strings and veins throughout the surrounding serpentine.

Augite.

A few large crystals of a green augite may be seen, while a considerable quantity of amphibole is also present. Of the latter mineral there are two varieties, both of which are monoclinic. Of these, the first is a common brown hornblende, with fairly strong pleochroism. The second variety

Amphibole.

occurs in strings and small isolated, but broken crystals. It is highly pleochroic, the colours ranging through violet, greenish-blue and blue to greenish-yellow, and in some cases pale yellow. No cross-sections with well-defined outlines could be detected; a few imperfect cross-sections of the prism, however, occur. In these, the cleavage cracks parallel to (110) intersect at angles of 123°½ to 124°½. Vertical sections also occur giving very low extinction angles, *viz.*, 4°½—6°. The above characters point to the fact that this mineral is glaucophane, the pleochroism strongly resembling that of glaucophane, as figured by Teall in his "British Petrography,"[1] rays vibrating parallel to α giving yellow to greenish-yellow, those parallel to β violet and those parallel to γ blue.

Magnetite.

Magnetite is almost entirely absent, a very few small grains occurring in the hornblende.

[1] See J. J. Harris Teall, British Petrography, Pl. XLVII, fig. 2.

Gabbro.—The gabbros are as well represented as the serpentines, but are considerably more varied in composition, the forms without olivine being the most numerous. Olivine-gabbros, however, also occur, and include a very good specimen

Troktolite.

of "forellenstein," the troktolite of von Lasaulx.[1] This specimen was found in the bed of the Tochi river, and is a portion of a rolled pebble. A rock of very similar composition, however, occurs *in situ* between Dotoi and Sheranni. The specimen from the Tochi river—No. $\frac{10}{811}$—is composed of a bluish-grey felspar, in which are set the numerous dark, rounded patches of olivine. Its specific gravity is rather low, being only 2·80: this however, is due to the fact that the rock has undergone very considerable alteration.

Under the microscope, it is seen to be composed chiefly of plagioclase and

Microscopic characters.

olivine, the remaining minerals being either of secondary origin or very subordinate in quantity. These include enstatite, augite, diallage, hornblende, bastite, epidote, serpentine and magnetite.

The plagioclase occurs in large irregular rounded crystals, giving clear sections

Felspar.

and broad lamellar twins. Referred to the plane of composition, the twin-lamellæ give extinction angles of 49° and upwards, while sections showing either basal or brachy-pinacoidal cleavage give high angles of 37° and 38°. These characters indicate that the felspar is anorthite.

As a rule, this anorthite is fairly fresh, except in the neighbourhood of the olivine crystals. Where it surrounds that mineral, it is penerated by a series of branching fissures, radiating from the olivine crystals and filled with decomposition products.[2] In other cases, however, it has a tendency to become saussuritic, with the development of grains and strings of epidote.

The olivine occurs in large crystals, either colourless or brownish-yellow, and

Olivine.

may be seen in many stages of alteration. In some cases it is fairly fresh, being merely intersected by cracks filled with serpentine and dusty magnetite; in the majority of cases, however, it is considerably altered. This alteration takes chiefly three different forms:

1. Into serpentine.

2. The olivine crystal has become to a great extent converted into a felt of fine hornblende needles, with some serpentine and magnetite = *pilite* (Becke).

3. All except the centre of the crystal has been converted into hornblende and magnetite. In this case, however, we do not find the typical reaction zones between the olivine and the felspar; the usual colourless inner zone being entirely absent, while the hornblende is a confused mass of plates and fibres surrounding and penetrating the still unaltered portion of the olivine crystal, and even scattered through the neighbouring felspar. In cases of still further alteration, almost, if not quite the entire crystal of olivine has disappeared, and been replaced by a brecciated mass of hornblende fragments. This hornblende is often colourless in section, but is at times of a very pale green colour, in which case it is slightly pleochroic. It would therefore appear from the above facts, that the customary reaction zones had originally formed round the olivine, where that mineral adjoined the felspar; the rock then underwent dynamo-metamorphism,—a fact which is also borne witness to

[1] Von Lasaulx: Elemente der Petrographie, p. 315.

[2] See Judd. On the gabbros, dolerites and basalts of tertiary age in Scotland and Ireland. *Quart. Journ. Geol. Soc.*, Feb. 1886, Vol. XLII, p. 86, and Plate VII, fig. 7.

by the traces of foliation in the hand specimen—, the zones thus becoming broken up into a confused breccia of hornblende with some felspar fragments. In other cases, the synthetic twinning of the hornblende also gives evidence of the pressure that the rock has undergone.

Augite.

The remaining minerals in the rock include a pale green augite, which is highly ophitic, in some cases extinguishing simultaneously throughout the whole slide.

Rhombic pyroxene.

Secondary minerals.

A considerable quantity of enstatite is also present and may often be seen passing into bastite, while epidote, calcite and magnetite are among the secondary minerals, the last-named however, being in a few cases apparently one of the original constituents.

A very similar result of the great pressure to which all these rocks have been subjected, is strikingly illustrated by a specimen of gabbro (No. $\frac{10}{817}$) from the Tochi river. This rock appears to have been originally composed of plagioclase and augite: the augite is now represented by diallage, veiy highly schillerized and invariably surrounded by a zone of highly pleochroic green hoinblende, which mineral has in many cases replaced the greater part of the diallage. This hornblende has again been broken up into a mosaic of pleochroic fragments, and is often to be seen intermingled with the felspar, and containing a considerable quantity of magnetite.

Gabbro without olivine.

The olivine-free gabbros are very numerous and occur in many stages of alteration. The majority, however, are much altered, the felspar having become saussuritic. This saussurite is chiefly of two kinds: (1) an indistinct, greyish mass, containing and often to a great extent composed of grains and, at times, large crystals of zoisite—No. $\frac{10}{814}$— and (2) a clear groundmass of albite in which are scattered numerous grains and long prismatic crystals of epidote—No. $\frac{10}{816}$—; a form of alteration first recognised by Cathrein.[1] The diallage also has to a great extent passed into a green hornblende, which usually shows the effect of metamorphism.

Felspar.

The freshest specimen—No. $\frac{10}{812}$—is part of a pebble from the Tochi river-bed, and contains felspar, enstatite, diallage, hornblende, magnetite and some epidote. The felspar, which is labradorite, is wonderfully fresh, only in a few cases showing signs of the formation of epidote.

Diallage.

Hornblende.

The diallage occurs in large quantity and is usually surrounded by an alteration-zone of hornblende, or else entirely converted into that mineral. The hornblende is both uralitic and actinolitic, the pleochroism of the latter giving green, brownish-green and bluish. Fibres may also be seen running along the cracks and twinning planes of the felspar. A considerable quantity of magnetite occurs in the hornblende. Under the microscope, this rock very strongly resembles the hornblende-gabbro of Crousa Down in Cornwall, figured by Teall in his "British Petrography," Pl. XVIII, fig. 2.

Magnetite.

[1] Cathrein. Ueber Saussurit, *Zeitschr für Kryst.*, 1883, Bd. VII, 234, also Teall, British Petrography, p. 149 *et seq.*

Altered gabbro with glaucophane.

Of the remaining gabbros, only one calls for special mention. This rock —No. $\frac{10}{818}$ — consists of pseudomorphs after felspar, and large quantities of monoclinic pyroxene (augite and diallage), with their alteration-products. The chief interest of the rock centres in the pyroxene. Under the microscope it is seen to be considerably altered; in a few places being converted into patches of brown hornblende; in most cases, however, the crystals are surrounded by a border of a clear blue mineral, which also runs along the cracks in the pyroxene and occurs in rods and patches in the neighbourhood of that mineral. It is highly pleochroic, giving violet, pale yellow and a clear sky-blue. On vertical sections, the angle of extinction is very small, not rising above 3° or 4°. This mineral is therefore glaucophane, and as in the gabbros of Attica,[1] is, together with the brown hornblende, an alteration-product of the diallage.

Pyroxene.

Glaucophane.

Dolerite.—In the hand-specimens, the dolerites appear fairly compact, and are of a greenish-grey colour, with a specific gravity ranging from 2·84 to 2·87.

They are chiefly composed of plagioclase and augite with their respective alteration products. They are, in all cases, much altered, and contain numerous secondary minerals, such as epidote, leucoxene, calcite, etc., with much micropegmatite, and at times appear under the microscope to be merely a mass of decomposition-products.

Constituent minerals.

The least altered of these rocks—No. $\frac{10}{800}$ — consists of a triclinic felspar, augite, enstatite, hornblende, apatite, magnetite and ilmenite.

Felspar.

The felspar is much altered and often converted into saussurite with the development of epidote. It shows, however, the broad lamellar twinning characteristic of labradorite.

Augite.

The augite is usually pale green; but in the least altered specimen a considerable quantity of colourless augite occurs in the form of small crystals and fragments, frequently twinned, but it is more often to be seen passing into hornblende or into pale green structureless *viridite,* with no apparent cleavage, but which ultimately passes into uralite or into chlorite.[2]

Ilmenite.

Ilmenite occurs in considerable quantity, some of the crystals showing signs of alteration into leucoxene.

Altered dolerite.

Two other specimens, *vis*, No. $\frac{10}{778}$ from Dotoi, and No. $\frac{10}{784}$ from Insar Kach, may very possibly be further stages in the alteration of the above rock. In the first, the whole of the augite has passed into viridite, and into a highly coloured brown hornblende, which surrounds, or occasionally occurs in patches in, the viridite, this latter passing into hornblende, and both being intimately connected with one another. As in the gabbros, signs of considerable dynamo-metamorphic action may be seen in this specimen, the hornblende being crushed and squeezed out into acicular rods and often scattered through the felspar. The large quantity of this mineral is very striking, and were

[1] See Zirkel Lehrbuch der Petrographie. 1894. Bd. III, p. 787; also Bd. I, p. 310.

[2] See Judd. *loc. cit.*, p. 85.

it not for the presence of labradorite in place of oligoclase, the rock might be more properly classed as a diorite.

Epidote.

Leucoxene.

Much epidote occurs in the felspar, which is rapidly becoming saussuritic and times schillerized.

Leucoxene and sphene also occur, no unaltered ilmenite remaining.

Microscopic characters.

Basalt.—The volcanic type of the basic rocks is represented by a specimen of amygdaloidal basalt—No. $\frac{10}{828}$ —which was found in the bed of the Tochi river. In the hand-specimen this rock shows white amygdaloids of calcite and zeolites, while a considerable quantity of porphyritic augite occurs. The ground-mass consists of innumerable small crystals of augite and apatite, with magnetite, decomposed plagioclase and brown glass. The augite, however, is by far the most important constituent. On rotation of the polariser, the rock is also seen to contain numerous flakes and fibres of a brown pleochroic mineral, which, under a high power, proves to be a dark mica; it occurs in flakes, as a rule without well-defined outlines. In addition to the above minerals, some secondary hornblende occurs, arising from the alteration of the augite.

The amygdaloidal cavities contain calcite and a zeolite, and their form indicates that these minerals are pseudomorphs after olivine and felspar, of which the original outlines have been retained. In one case, even the cleavage of the olivine appears to have been preserved, although that mineral has been replaced by calcite. All the porphyritic felspars and olivines, however, have been replaced, the only remaining felspar being the small decomposed crystals in the groundmass.

The augite is of the usual type, being frequently twinned and beautifully zoned.

Trachyte.—No $\frac{10}{705}$.—This is a compact light bluish-grey rock, with a specific gravity of 2·60. It was obtained from a spot one mile to the west of Pakki Kot, and is of subsequent date to the accompanying shales, into which it has been intruded, and which are burnt and altered at the junction. In the hand-specimen, it appears to consist of a grey lithoidal groundmass, through which are scattered numerous small white crystals of felspar, some occurring in groups of small individuals, while other larger crystals occur singly.

Plagioclase.

Sanidine.

Under the microscope, the rock is seen to be composed of a fine microscopic groundmass of felspar microlities, in which are embedded porphyritic crystals of plagioclase and sanidine. The plagioclases are much the smaller, and occur as a rule in groups, the crystals showing broad lamellar twinning. They are considerably altered, thus constrasting with the beautifully clear pellucid crystals of sanidine, which have idiomorphic outlines and are quite fresh, with but few inclusions. No ferro-magnesian minerals can be detected, the rock being composed merely of felspar with a large quantity of magnetite.

Bronzite-hypersthene rock.

The remaining igneous rocks include specimens of porphyrite, diabase, bronzitite, bronzite-hypersthene rock and a rock composed of fibrous actinolite. The bronzite-hypersthene rock is composed of very large crystals of those minerals, some

of the individuals measuring as much as two inches across. This specimen comes from the hills to the north-west of Sheianni, while a specimen of bronzitite which is of finer texture, and is composed entirely of bronzite with some magnetite was found in the bed of the Tochi river.

Bronzite.

An interesting rock, also, comes from the river to the east of Dotoi. This is a heavy, green crystalline rock, of hardness = 5, or slightly higher, and a specific gravity of 3·25. It bears a strong resemblance, in the hand-specimen, to dunite, but under the microscope it is found to contain no olivine, while chemical analysis proves it to be composed chiefly of calamine ($H_2\ Zn_2\ Si\ O_5$), with smithsonite ($Zn\ Co_3$) and some zinc blende. A few cracks in the specimen have become filled with calcite. This rock bears a close resemblance to the massive calamine of Altenberg in Rhenish Prussia. It was apparently not obtained *in situ*, being rolled and waterworn.

Calamine-Smithsonite.

The remaining rocks include recent river breccias, also specimens of red and green jasper from the Tochi river, and a few metamorphic rocks, amongst which are garnetiferous mica-schist, calc-schist, and baked shales.

The baked shales occur in contact with the igneous rocks, and have been more or less fused; some have been much altered, showing signs of considerable fusion and having a hardness of 6 or more, while under the microscope they are seen to consist of a glassy groundmass, containing in places small crystals, which appear to be the product of recrystallisation.

Baked shale.

Notes from the Geological Survey of India.

Rewah.—Among the fossils from the lower Gondwanas collected during the past working season, is a clump of *Glossopters* fronds, attached to a portion of their root stock. The specimen is not so well preserved as might be wished, but the fronds are readily enough recognised and the fragment of root-stock shows the characters of *Vertebraria*. In the Comptes Rendus of this year M. R. Zeiller, under date 23rd March, described the discovery of *Glossopters* fronds attached to *Vertebraria* in the Transvaal, so the true nature of *Vertebraria*, long in doubt, may be taken to be settled as the root-stock of *Glossopters*. A figure and description of the Rewah specimen will be published.

Burma.—Mr. Hayden visited and examined the steatite mines supposed to be in the Minbu district, but really situated to the west of the Yoma in the Kyakpyu district of Arakan. The steatite occurs in thin bands and lenticular patches in the serpentine intrusions of the Arakan Yoma and is of great purity.

Kelat.—A collection of fossils from the hills near Kelat has been made by Lala Kishen Sing. The fossils have not yet been examined, but the discovery of *Orthocerus* by Dr. Carter (see Manual, 2nd edition, page 143) does not seem to have

been repeated. The most interesting stratigraphical fact to record is the direct contact of uppermost nummulitic (Spintangi) beds with the massive (jurassic) limestone, which had in one place been eroded till only 15 to 20 feet remained out of 300 feet seen close by.

R. D. OLDHAM.

DONATIONS TO THE MUSEUM.

FROM 1ST MAY TO 31ST JULY 1896.

Native Gold, with pyrites, in quartz, from the Chowkpazat Gold Mine, Wuntho, Burma
PRESENTED BY C. M. P. WRIGHT.

Specimens of pegmatite; muscovite with schorl; and biotite and muscovite in parallel crystals, from Bendee, Hazaribagh district, Bengal.
PRESENTED BY A. GOW SMITH.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF

Part 4.] 1896. October.

Report *on the* Steatite mines, Minbu District, Burma, *by* H. H. HAYDEN, B.A., B.E., *Assistant Superintendent, Geological Survey of India.*

The two chief localities from which steatite is obtained in or near Minbu district are—

(1) the steatite mines some 30 miles west of the village of Hpa-aing; and

(2) the lately discovered mines near the village of Senlan in Ngapè township.

Steatite mines west of Hpa-aing.

Of these, the former are the older and the more important. They lie on the western side of the Arrakan Yoma, and, though supposed to be situated in Minbu district, are in reality some ten or fifteen miles over its western boundary[1]; they are, therefore, in the Kyaukpyu district of Lower Burma. Owing, however, to the erroneous impression prevailing as to the situation of the mines, and also to the fact that no information on the subject was obtainable in Minbu, I was unprovided with maps of Kyaukpyu district and can therefore indicate only the approximate position of the mines.

Accessibility.

The march from Hpa-aing occupies four days, the path running straight up and down the steep, jungle-clad sides of the Arrakan Yoma. The chief means of transport are pack bullocks. which carry loads ranging from ten to thirty viss[2]. The mountains, which are covered with dense jungle, are uninhabited, the last village—Thet-kai-kyin—being reached at the end of the first day's march from Hpa-aing, while the subsequent halting places are merely clearings in the jungle with no huts or other shelter.

History.

These mines have been worked for many years, having been in active operation before the annexation of the country by the British.

The mines.

Mining is carried on from October till the end of April or beginning of May, when work is abandoned on account of the rain.

The steatite occurs in veins traversing the dark green, intrusive serpentine, which is found in such large quantities in the Arrakan Yoma. This rock (serpentine) is

[1] One mine only, Hpo-gyi-dwin is situated in Minbu district. This is an old disused pit on the eastern slope of Hpo-gyi-taung.

[2] One viss = $3\frac{1}{2}$ lb approximately.

in most cases found to contain steatite: frequently, however, merely in narrow ribbon-like veins. In places, these veins increase in thickness, attaining a width of eight or nine inches. When a band is found which is judged to be worth working a shaft is sunk along the vein and the steatite extracted till the vein is exhausted. During this process, other bands are frequently met with, and thus the shafts are found to ramify in all directions.

The total number of mines, including many not now in operation, amounts to about twenty-six. Of these only four were being worked at the time of my visit (May, 1896), and, owing to the fact that the rains had set in, work was abandoned soon after my arrival.

The four mines above mentioned were, however, fully examined, and may be described in the order in which they were visited.

(*a*) *Badwin*.—This mine is situated at about three miles south-west of Thit-myit-kyi, the halting place reached at the end of the third day's march from Hpa-aing. Two pits only are at present worked, but numerous old shafts, now either worked out or neglected, are seen in the neighbourhood. The present pits were unfortunately, at the time of my visit, unfit for descent owing to the large amount of rain which had already fallen: the sides and roof had already begun to fall, and consequently work had been abandoned. Considerable quantities of steatite, however, had been extracted and packed in baskets ready for removal. The steatite is of good quality and the miners say that the quantity still available is considerable.

(*b*) *Sambawgyi dwin*.—This mine is reached at the end the fourth day's journey, and is one of the most important. Here also only two pits are now worked, though the remains of nearly a dozen can be seen. Of these two pits, one had just become too unsafe to work, but the other (the better of the two) was still in operation, although, owing to the rain, much débris had already begun to fall. I succeeded, however, in descending and fully examining this shaft. The mining is of the most primitive type, and a short description may be of inte rest.

The mouth of the pit is nearly four feet square, and from this the shaft descends vertically to a depth of 56 feet. The sides are timbered for the first forty feet to prevent falls of rubbish. Below this depth the ground becomes firmer and through it the shaft is sunk vertically for 16 feet more; from this point, it slopes steeply in an easterly direction for 17 feet, then follows a vertical descent of 8 feet, after which the shaft slopes in a south-easterly direction, with numerous turns and steep descents, to a distance of 200 feet.

The size of the shaft is very variable, being at first nearly four feet square. After this, however, it narrows considerably and is usually only just large enough to allow of the passage of the miner, crawling on his hands and knees. In places, however, even this becomes impossible, and it is necessary to lie down and work one's body through narrow passages as much as ten feet or more in length. This is rendered even more unpleasant by the large quantity of water collected on the floor of the shaft, wherever it may chance to be level.

When, therefore, the rains have set in, and the roof and sides become soft and liable to fall, descent becomes a matter of extreme danger since a comparatively small fall of débris would completely block the passage. In addition to this, the entire absence of any form of ventilation is most trying. After descending to a

depth of some eighty feet or so the atmosphere becomes stifling and one experiences great difficulty in breathing. In fact, ventilation takes place solely by means of diffusion, which, in such narrow and tortuous passages, is a very slow and unsatisfactory process.

The steatite occurs in this shaft in two bands, seven and eight inches wide respectively. The mineral is fairly compact and of good quality, though in places it is crushed and useless.

(*c*) *Sambawgalè dwin.*—This mine is situated at about a quarter of a mile east of Sambawgyi. It also contains two shafts yielding good steatite.

(*d*) *Omyè dwin.*—This, though one of the oldest, is still the best mine now in operation. It is said to have been worked in the time of the last Burmese king, but has for some years been neglected, having only recently been re-opened. Only two pits are at present worked, and of these one had already been closed at the time of my visit, but the other was still in operation.

The shaft descends vertically for a depth of 45 feet, then branches into two narrow passages, running east and south-east respectively. Of these, the former descends steeply for ten feet, but work has been interrupted by the influx of water, which has necessitated the erection of pumping machinery; the other passage run for some fifteen feet to the south-east and contains a fine 9-inch band of steatite of great purity.

Extraction of the steatite.

The steatite is cut out from the surrounding serpentine by means of chisels. The broken pieces are then collected into small baskets and carried to the foot of the vertical shaft, whence they are drawn up to the surface by means of balance-poles.

Picking and cutting.

On reaching the surface the steatite is picked over, all worthless pieces being discarded. It is then sawn up into blocks of various sizes, chiefly into pieces of about 8″ × 3″ × 3″ and into pencils ½ inch square in section and of varying length. The pieces are sorted and packed into panniers, and are then ready for removal.

2. The second set of mines is situated some 12 miles to the west of Shauktaung, (Shodan of map) in Ngapè township.

From Padein a fairly good cart track runs to Shauktaung, but from this latter village the remainder of the journey must be performed on foot.

From Shauktaung, a rough jungle path leads to a small Chin village named Won situated in the heart of the Arrakan Yoma and near the source of the Mankyaung. From Won a path runs to Senlan, a still smaller village, some 3⅝ miles further west. The steatite mines are situated at about 2 miles (by path nearly 5 miles) due west of Senlan on a steep mountain side overlooking the Mankyaung.

These mines were discovered a few months ago by some natives of Padein, who extracted a considerable amount of steatite before the matter was brought under the notice of the authorities.

There are nine pits in all, but of these several proved unproductive, only a few yielding sufficient steatite to be worth working.

These, however, have been carried down to at least 50 feet in depth, and probably considerably further. Owing, however, to the work having been interrupted, the pits have been deserted and descent is now impossible.

The steatite, which is of good quality, was extracted in large blocks, which in some cases attained a volume of half a cubic foot. These were sawn into smaller

pieces and into pencils, which were then buried beneath the floors of the miners' huts to be carried away as occasion offered. It is stated that when work was prohibited some 350 viss had already been removed: a large quantity, however, has been left behind and still remains in baskets buried beneath the huts.

Both the quantity and quality of the steatite here found point to the fact that the mines are worth working.

Value of the mines.

It has already been pointed out that the steatite occurs in veins in serpentine. In some cases the band of steatite rapidly dies out, but in others it may continue for several hundred feet. The steatite mining is therefore purely a matter of chance, for a vein may die out at any minute, and it is quite impossible to form any opinion as to the amount of steatite likely to be obtained from any given vein. It will, therefore, be evident that any statement as to the amount of this mineral available at the mines would be purely conjectural. All that can be said with any certainty is that the dark green serpentine appears to occur in very large quantities in the Arrakan Yoma, and where seen is usually found to contain steatite and that frequently in paying quantities, while the great purity of the mineral itself considerably enhances its value.

Geology.

The geology of Minbu district has already been described by Dr. Noetling in his paper on the "Development and Sub-division of the tertiary system in Burma[1]". From the map accompanying his paper, it will be seen that the upper tertiary rocks extend from Minbu to the foot of the Arrakan Yoma. Owing to the early date at which the rains set in on the Arrakan Yoma, I was forced to travel as rapidly as possible over this portion of the country, and was therefore unable to do more than remark the excellent exposures of tertiary rocks seen between Aingma and Ngapè, and the beautiful sections extending from Kyiwa to Mézali, along the banks of the Mon river, which cuts through the inclined tertiary strata, exposing an almost perfectly continuous section for many miles. Between Aingma and Ngapè are seen great beds of sandstone and clay. The sandstones contain many fossiliferous bands, which, though individually narrow, are both numerous and highly productive. As the road approaches Ngapè, the sandstones become unfossiliferous and between that place and Shauktaung, the beds appear to contain no recognisable organic remains. At about half a mile west of Shauktaung the sandstones are underlain by thick beds of very finely laminated dark shale with occasional carbonaceous bands. In these shales occur at first narrow bands of sandstone, and beneath these a thick bed of grey limestone, with nummulites in places: as a rule, however, in this neighbourhood, the limestones have been altered to such an extent by outbursts of a dark green serpentine, that the fossils are not recognisable. Beneath these limestones come—

(1) a bed of very dark purple schist, containing some limestone bands, and succeeded by

(2) an immense thickness of green and purple shales, containing enormous quantities of vein-quartz. These rocks (1 and 2) are presumably the "Chin shales" of Dr. Noetling.[2]

[1] Records G. S. I., Vol. XXVIII, Pt. 2, p. 59, sqq.

[2] Loc cit.

In the neighbourhood of Shauktaung, the tertiary beds dip to the east at an angle of 40°, and form parallel ranges of low hills running north and south and bordering the Arrakan Yoma. These rocks show no signs of alteration. As soon, however, as the "Chin shales" appear, a remarkable change is noticed: the rocks then become folded, crushed and faulted, and in this condition form the greater part of the Arrakan Yoma. At about 1½ mile west of Shauktaung the "Chin shales" first appear and continue without interruption to Won. About 1¼ mile west of Won they are well seen in the steep, precipitous sides of the Mankyaung. Here also occur numerous dykes and intrusions of a grey dolerite, which is seen in great masses in the "Chin shales". Numerous boulders of dark green serpentine and a somewhat fine grained green gabbro occur in the stream-bed. Two and a half miles west of Senlan are found large quantities of the above serpentine. The rock has been much crushed and in places strongly resembles the "Chin shales." It contains numerous veins of steatite, and it is here that the new mines already described have been opened.

The general strike of the rocks being north and south, the same beds are met with in the journey from Hpa-aing to the older quarries. A few points of difference are, however, noticeable. One of these is the much smaller quantity of vein-quartz found in the "Chin shales". Another very interesting feature of the rocks here is formed by numerous strings of quartzite pebbles and boulders enclosed in these shales: these enclosures are of all sizes and range from blocks weighing several tons down to fragments an inch or so in length. They appear to lie along the cleavage planes, with their long axes in the direction of strike of the cleavage. The enclosures are well seen in the Kyikyaung, at the halting place reached at the end of the third day's march from Hpa-aing. Here, too, a band of quartzite is seen interbedded with the shales. The appearance of the shales and their enclosures so exactly resembles that of the quartzite pebbles and boulders seen in the cambrian slates on the peninsula of Howth, near Dublin, that one is constrained to assume a similarity in their mode of origin.

This latter phenomenon has been described by Professor Sollas, who writes:— "...on the north side of Howth one may observe how great blocks of quartzite have been squeezed out from their bed during folding and carried into a stream of flowing slate, to form veritable intratelluric erratics. Near the nose of Howth whole trains of such erratics may be seen; these, no doubt, stand in connection with an important plane of shearing along the middle limb of an overfold....The whole terrane seems here to have been thrown into a state of intestine movement flowing up, down and sideways, and even whirling round about." [1]

The boulders of quartzite are in some cases so large as to preclude the probability of their having been waterborne, while at the same time their exact resemblance to the neighbouring bed of quartzite is strong evidence in favour of their having been derived from it.

The amount of pressure to which these shales have been subjected, though probably not so great as that which the Howth rocks have repeatedly undergone since cambrian times, has, nevertheless, been sufficient to elevate the great mountains of the Arrakan Yoma, and to fold and contort the shales to a vast extent. The

[1] Proc. Geologist's Assoc., Vol. XIII, Pt. 4, 1893. The Geology of Dublin and its neighbourhood.

cleavage and bedding of the shales appear to correspond and, where not vertical, the prevailing dip is at a high angle (80° and over) to east or west. Everywhere overfolds, faults and broken-backed anticlinals are seen, and it is almost impossible to estimate even roughly the true thickness of these beds which extend, at any rate in the neighbourhood of Shauktaung and Won, over more than six miles of country. Nor does the possibility of the discovery of fossils in beds which have been so crushed seem to be anything but exceedingly remote.

Further notes *on the* Lower Vindhyan (Sub-Kaimur) area *of the* Sone Valley, Rewah, *by* P. N. DATTA, B.SC., F.G.S., *Deputy Superintendent, Geological Survey of India.*

'Lower Vindhyan' area surveyed this season.

The area surveyed in 1895-96 includes the ground bounded on the north by the Kaimur scarp and on the south by the Sone River, and extending from the neighbourhood of Churhat (Lat. 24° 25′·5, long. 81° 42′·5) on the west, to the extreme limits of the State of Rewah on the east.

Combined extent of Lower Vindhyan areas surveyed during 1894-95-96.

Thus the lower Vindhyan area examined on the west during the season 1894-95 together with that surveyed this season (1895-96) on the east makes up almost the entire strip of land situated between the Kaimur scarp on the north and the Sone on the south, in the Rewah State.

Lower Vindhyan beds classified into four stages.

As the result of my examination of the ground during the season 1894-95, I found that the lower Vindhyan system clearly admitted of arrangement into four broad, well marked stages,[1] namely, the Rhotas, Kheinjua, Porcellanic and Conglomeratic stages, in place of the eleven 'subdivisions' into which Mr. Mallet had proposed to classify it.[2] My examination this season (1895-96) of the eastern continuation of the same beds, as were met with during the season 1894-95 in the western parts, has further convinced me that Mr. Mallet's subdivisions of the lower Vindhyan system are not tenable.

Mr. Mallet's eleven 'subdivisions' not tenable.

For while some of these subdivisions are extremely limited in extent, being in fact altogether more or less local, beds have been made to form a subdivision which are not only local but also not very definable; and again, many of the proposed 'subdivisions,' through lack of possession of characters important and distinctive enough, are not entitled to the rank of 'stages' properly so called. Under these circumstances the classification of the lower Vindhyans into the so-called subdivisions, eleven in number, can hardly be retained, and their arrangement into the four stages, Rhotas, Kheinjua, Porcellanic and Conglomeratic, seems about the best we can have under our present state of knowledge.

[1] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 145.
[2] Mem. Geol. Surv. Ind., VII, p. 28.

We will take up the stages severally and notice the peculiarities, should there be any, in their extension in the eastern area. Beginning with the youngest we have the—

Rhotas stage. Limestone is of the same character as on the west.

Rhotas.—Though the bulk of the stage is concealed under alluvium in the eastern parts. it is apparently composed of thin-bedded limestone of much the same kind and character as on the ground to the west.

Shaly band, No. 10 of Mallet's subdivisions, not traceable.

The band of argillaceous shales stated to occur in the upper parts of the stage forming subdivision No. 10 of Mr. Mallet[1] could nowhere be clearly seen in the area under report. These shales are, however, stated to occur between Rajgurh and Rewasin Hill.[2] That Rajgurh is probably a misprint for Ramnaggar would appear from the occurrence of a locality of the name of Ramnaggar in about the identical position of 'Rajgurh' in the map accompanying Mr. Mallet's Memoir. Taking Ramnaggar and Reiwas Hill then for 'Rajgurh' and 'Rewasin' Hill, hardly any clear exposures of even the upper beds of the stage are obtainable in this area, to say nothing of an intercalated band of shales in them. But certainly at the foot of the scarp by Baghawa (Lat. 24° 29', long. 81° ·50'), Diholi (Lat. 24° 30', long. 81° 53'), and a few other localities, I observed debris of what looked like argillaceous shales; but as in none of these places could I discover any indications of lamination or bedding in them it was not possible to make sure whether what was observed was the debris of the Bijigurh shales washed down the slopes from above or really shales *in situ*.

Kaimur-Rhotas junction.

As to the junction of the Rhotas limestone with the Kaimurs above. In my report of last year I gave it as the result of my examination of the Kaimur-Rhotas junction in the area from N.W. of Intwa, *i.e.*, about long. 81° to near Churhat (long. 81° 38') that no evidence of unconformity was discovered at this junction, but there were, on the contrary, indications of a gradual passage from the Rhotas limestone into the Kaimur beds above, this passage being indicated by a fine grained, homogeneous chalky shale, as exposed by Hinaota, Daorahra, Majgama, etc.[3] The examination of the ground was extended this season from long. 81° 38' to long. 82° 30', and the following sections are of interest as bearing on the question of the nature of the junction of the lower Vindhyans (Sub-Kaimurs) with the upper Vindhyans:—

Sections bearing on the nature of the junction. Ginaor section.

Ginaor.—(*Lat. 24° 27''5, long. 81° 42'*).—There are two little hillocks at the foot of the Kaimur scarp by this village. At the eastern extremity of the western hillock is exposed a gentle anticline formed by sandstone (Kaimur), in the centre of which is seen a darkish grey subporcellanic rock exactly like that observed last season between the Rhotas limestone below and the Kaimur beds above. This subporcellanic shaly rock passes up into a light gray laminated soft shale which is overlaid by the sandstone forming the top beds of the anticline. This sandstone is the continuation of the lowermost beds of the sandstone exposed on the adjoining Kaimur scarp. The Rhotas is not exposed here, but there is little doubt but that it comes in just below the subporcellanic shaly beds. Thus all

[1] Mem. Geol. Surv. Ind., VII, pp. 28, 42.
[2] Mem. Geol. Surv. Ind., VII, pp. 42, 43.
[3] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 149.

that we can see here is that the subporcellanic silicious shaly rock passes up into a soft light grey shale which in turn seems to pass up into the sandstones of the Kaimur scarp.

Tikat section.

Hillocks by Tikat (*Lat.* 24° $28'\cdot5$, *long.* 81° $46'$).—There are three little hillocks here at the foot of the Kaimur scarp. Rising as they do from the alluvium of the plains, these hillocks are seen to be composed of subporcellanic silicious shales, which are well exposed on their southern slopes, and are capped by thin-bedded sandstone. No marked thickness of laminated soft shales occurs here, but these seem to be immediately overlaid by the sandstone. The uppermost shaly rock does not seem to be an admixture of argillaceous and arenaceous materials, but while the shale is exceedingly fine grained and seems argillaceous (but may be somewhat silicious) the sandstone seems entirely arenaceous and is not very fine grained. Thus there appears to be here an absence of a true passage of material from the one set of beds into the other. But though this is so, there is a perfect parallelism of bedding between the shales and the sandstone. The Rhotas below the subporcellanic shales is not exposed here.

Baghawa section.

Baghawa (*Lat.* 24° $29'$, *long.* 81° $50'$).—The foot of the scarp slopes N.-W. of Baghawa, exposes sections exactly similar to those near Tikat. Here, at one spot, the topmost layer, 2″ thick, of the silicious shale could be traced for a few yards along the junction with a perfect dip-conformity with the overlying sandstone, although in the character of the constituent materials the shales and the sandstone were sharply separated, one being of fine argillaceous material (might be somewhat silicious) and the other purely arenaceous.

Diholi section.

Diholi (*Lat.* 24° $30'$, *long.* 81° $53'$) — At a point at the foot of the Kaimur scarp N. by W. of Diholi is seen a section quite similar to the preceding, but here the limestone (Rhotas) is exposed in addition, underlying the subporcellanic silicious shales. These shales are very well seen here, being light to dark grey in the lower parts and rather finely laminated in the upper parts. The junction of the sandstone with these shales is as in the preceding section, but the contact of the latter with the underlying Rhotas is not exposed. A couple of shallow pits were dug here with a view to getting at the contact but the digging was abandoned owing to prevalence of sandstone and shale debris. The point of interest, however, here is that all the three sets of beds, namely, the Rhotas, the superjacent silicious shales, and the sandstone overlying the last, are all well exposed exhibiting a perfect parallelism of bedding between one another.

By *Maraoli* (*Lat.* 24° $33'\cdot6$, *long.* 82° $20'\cdot25$), *and Khairpur* (*Lat.* 24° $34'$, *long.* 82° $25'$).—Rhotas is visible by the foot of the scarp slopes, but the junction with the beds above is obscured by talus.

Hurma (*Lat.* 24° $31'\cdot5$, *long.* 82° $34'$).—On the scarp slopes here the limestone (Rhotas) is followed up the slopes for some way, but its junction is more or less obscured by shaly debris from above.

Ground E of Hurma.

Sections *E. of Hurma.*—In the ground eastwards of Hurma and as far as the limits of Rewah, fairly clear sections are not unfrequently met with; but the subporcellanic silicious shales between the Kaimur sandstone and the Rhotas limestone, hitherto noticed so often on the west, seem to be absent there. But the parallelism of the limestone beds of the

Rhotas stage with those of the overlying sandstone of the Kaimurs is maintained throughout.

Thus from the sections above recorded we find that while near Ginaor the subporcellanic silicious shales pass up into a shale which in turn seems to pass up into a sandstone, this latter shale is little developed by Tikat. Throughout the greater part of the area in sheet 474 (*i.e.*, from long. 82° 0′ to 82° 20′) the rim of the upper Vindhyan basin seems depressed and the Kaimur sandstone comes down to the level of the alluvium of the plains. Eastwards of this point the Rhotas is again visible by the foot of the scarp, but the silicious shales are no longer traceable, being apparently absent, the result being that the Rhotas is in direct contact with the sandstone of the Kaimur scarp. These last two sets of beds, however, exhibit a thorough dip-conformity throughout.

Inferences drawn from the sections.

From these observations and those recorded last year we are led to infer:—

i. That there is a passage from the Rhotas limestone into the Kaimur sandstone through a homogeneous white shale, as observed by Hinaota, Daorahia,[1] etc., and a subporcellanic silicious shale which itself passes up into the overlying sandstone.

ii. That the above mentioned shales—the homogeneous white shale, the silicious shale, etc.—die out towards the east, and that there is an overlap of these by the Kaimur sandstone which thus rests directly on the Rhotas limestone in the eastern parts.

iii That this overlap would explain the abrupt juxtaposition of a coarse rock like the sandstone of the Kaimurs and of a fine-grained, homogeneous deposit like the Rhotas limestone, an abruptness that has hitherto been held to be universal and as such been insisted on as evidence of unconformity between the lower and the upper Vindhyans, but which appears now to be not universal but only local, obtaining over only parts of the area, and being replaced in other parts by a gradual passage from the limestone of the Rhotas into the arenaceous beds above.

iv. That though thus there is an overlap in certain parts by the Kaimur sandstone of the shales that come in immediately above the Rhotas, there is no unconformity between the lower Vindhyans (sub-Kaimurs) and the upper Vindhyans.

The Kheinjua stage.

Kheinjua stage.—As most of the area examined this season is under a general cover of superficial deposits, exposures for close examination of the beds were very few and imperfect, and thus it was not possible to arrive at a more minute and detailed classification of the Kheinjuas than that recorded last year.[2] Hence last year's classification of the

[1] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 149.

[2] These are the 8 zones into which the Kheinjuas were divided:—(Descending order).

i. Argillaceous shales, with calcareous concretions, etc.
ii. Limestone band.
iii. Shales, with thin-bedded sandstone, ripplemarked.
iv. Limestone, with shales: limestone ripplemarked, impure with quartz and other enclosures.
v. Shales, argillaceous and arenaceous, ripplemarked, with thin bands of sandstone.
vi. Sandstone, thick bedded and quartzitic.
vii. Limestone with shales.
viii. Shales and sandstones.

See Rec. Geol. Surv. Ind., XXVIII, p. 146.

Kheinjua stage, namely, into 8 zones, has been retained, and endeavour has been made to correlate the sections available in the eastern area with those of the western. The main results are that while zone i (upper part of Mr. Mallet's subdivision No. 8) and zone iv (subdivision No. 7 of Mallet's) are fairly persistent and traceable almost throughout the area, the limestone of zone iii is nowhere exposed in this eastern area, nor is the zone vii well defined, though a thin limestone band does occur in parts of the area not far from its horizon, such for instance as the calcareous band 1 mile S of Churhat (Lat. 24°25'·5, long. 81°42'·5). Zone iii no doubt occurs probably throughout the area though it is not open to examination owing to superficial deposits. The absence of the thick-bedded quartzitic sandstone band, *i.e.*, zone vi. (part of subdivision 6 of Mr. Mallet's) coupled with the circumstance that the limestone of the zone vii is not generally developed or traceable, adds to the difficulty of separating v from viii. Thus where there is no limestone in the lower parts of the division, zones v-viii are not distinguishable among each other.

Reported absence of limestone of zone iv, *i.e.*, of subdivision 7 of Mr. Mallet's at Bardhi.

Reference may here be made to one or two of Mr. Mallet's remarks recorded by him with reference to the Kheinjuas.—Mr. Mallet says that the limestone of his subdivision No. 7 is absent at Bardhi.[1] Now there can be no question that there is a broad band of limestone well exposed on either bank of the Gopat by the south-western end of the village of Bardhi, and that it occurs as part of the Kheinjuas and is overlaid by thin-bedded sandstones and argillaceous shales containing calcareous concretions which certainly belong to Mr. Mallet's subdivision No. 8[2], and is underlaid by shales and thin-bedded sandstone with some more beds (*i.e.*, the lowermost, probably shales) that are concealed. But as porcellanic shales (No. 5 of Mallet's) come in just below the last mentioned set of beds—the shales and thin-bedded sandstones—there can hardly be much doubt that these shales and sandstones represent his subdivision No. 6, and consequently the Bardhi band of limestone must belong to his subdivision No. 7. While the existence of the subdivisional limestone No. 7 is altogether denied at Bardhi, not only is there no position whatever assigned in Mr. Mallet's classification to the prominent band of limestone of Bardhi but it is not so much as even alluded to as occurring here.

Alleged absence of subdivisions 7 and 6 of Mr. Mallet's at Bardhi.

With regard to the statement that the concretionary shales (*i.e.*, part of Mallet's subdivision No. 8, or zone i of the Kheinjuas of my classification) rest directly on the porcellanic shales at Bardhi, and that consequently the intermediate beds (*i.e.*, his subdivision Nos. 7 and 6) are entirely undeveloped there,[3] the following section by Bardhi will make it at once evident that a good thickness of those intermediate beds (subdivisions 7 and 6) do occur there and that thus the concretionary shales of subdivision No. 8 do not rest directly on the porcellanics at or near Bardhi.

Section N. by W.—S. by E. by Bardhi.

(DESCENDING ORDER.)

a. Argillaceous shales, dark grey to blackish, containing calcareous concretions, passing down

[1] Mem. Geol. Surv. Ind., VII, p. 38. The locality is here named "Burdhee."

[2] Mem. Geol. Surv. Ind., VII, p. 40.

[3] Mem. Geol. Surv. Ind., VII, p. 38.

into a thin band of finely laminated light grey to whitish shale with crystals of quartz. Well seen on the left bank of the Sone, N. W. of Bardhi.

b. Blank.

c. Thin-bedded sandstone (with an occasional thick bed), with subordinate bands of shales. These are the beds on which Bardhi itself stands and are well seen on the right bank of the Gopat here.

d. Limestone with shales: composed of an upper band of grey, yellowish to pinkish limestone, thick bedded and cherty, succeeded by greenish argillaceous shales and these being underlaid by a thinner band of rather impure limestone with intercalations of arenaceous layer. Well exposed on the right bank of the Sone at 2½ miles W. by N. of Bardhi; seen also on the Gopat just S. W. of Bardhi itself.

e. Shales, greenish (argillaceous as well as arenaceous), with thin-bedded sandstone.

f. Blank.

Porcellanics.

In this section:

(*a*) represents zone i of the Kheinjuas, *i.e.*, uppermost part of Mr. Mallet's subdivision No. 8;
zone ii may be present but is not exposed;

(*c*) „ zone iii, *i.e.*, lower parts of 'subdivision' No. 8; and evidently the next lower beds, namely,

(*d*) represent zone iv, *i.e.*, subdivision No. 7 of Mallet's, and that

(*e*) and the concealed beds of blank f, represent v, vi and viii (vii in all probability being absent from the section), that is, subdivision 6 of Mr. Mallet's. Thus a tolerably good thickness of beds of 'subdivisions' 7 and 6 are interposed between the shales containing calcareous concretions belonging to No. 8 of Mallet's subdivisions and the porcellanics in the neighbourhood of Bardhi.

Trappoids generally absent.

Porcellanic stage.—Of the three-fold division of the porcellanics, namely, into upper porcellanics, trappoids and lower porcellanics, as indicated from the examination of the ground in the western parts,[1] the trappoids seem more or less absent in the area examined this season. They (the trappoids) being the coarser beds it is only to be expected that they would be more or less local in extent and distribution Thus in this eastern area the porcellanics consist generally of shales of a porcellanic character together with intercalations of ordinary argillaceous shales, with only very local, occasional, coarser beds—the remnants of the old 'trappoids'.

The porcellanics as a band are traceable as far as Agarwar (Lat. 24° 32′·5, long. 82° 41′·5). Eastward of this surface deposits predominate to such an extent as to conceal all further exposures, and the course indicated by the porcellanics is therefore to some extent conjectural.

Limestone of 'subdivision' No. 2 of Mallet's cannot be maintained as a subdivision of the basal stage.

Conglomeratic stage.—This, the basal, stage of the lower Vindhyans (sub-Kaimurs) was proposed last year to include beds of subdivisions Nos. 2 and 1 of Mallet's.[2] Further observations this season have not only convinced me as to the propriety of including the limestone of subdivision 2 in this stage, but also that the limestone forming Mr. Mallet's subdivision No. 2 cannot be maintained as a subdivision proper at all, but that it can be regarded only as a zone in the stage. For there is no limestone constantly present occupying a horizon intermediate between the porcellanics and the subdivision No. 1 (Mallet's); in fact in the area

[1] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 146.

[2] Rec. Geol. Surv. Ind., XXVIII, pt. 4, p. 147.

under report a limestone could be detected only for a few miles in this position. Even when it does occur in this position it is not present as a thick mass, nor does it exhibit any characteristic peculiarities entitling itself to any prominence, but on the contrary it shows an intimate connection and association with the underlying beds, as if it formed a part and parcel of them. Added to this is the circumstance that it does not present an uniform and persistent character in all its outcrops but is of a character exceedingly inconstant and variable. There certainly does occur in many places in the area under notice one thin calcareous band, or more, in this conglomeratic stage but the position of its occurrence varies, it being sometimes in the upper parts of the stage, sometimes about the middle and occasionally rather near the base than otherwise. So the arrangement of the conglomeratic stage into two subdivisions, namely, limestone and conglomeratic and calcareous sandstone that was suggested must be given up. As to any new grouping of the beds: Of the ground surveyed this season by me the conglomeratic stage comes in only in part of it and even in this limited area alluvium prevails over a large portion and thus exposures available for a minute examination were exceedingly few and unsatisfactory. Under these disadvantageous circumstances any attempt at a minute classification—a classification that would hold good generally—had to be given up and all that has been found possible is to suggest an arrangement of the beds of the stage into two broad subdivisions, namely :—

Horizon of the calcareous band or bands in this stage variable.

Classification of the beds of the stage into two subdivisions.

(DESCENDING ORDER.)

i. Shales and thin bedded sandstones, with one or more of calcareous bands.
ii. Sandstones, rather thickest bedded and often rather quartzitic, with conglomeratic quartzite or sandstone.

Notes from the Geological Survey of India.

Mysore.—During a recent tour of the Director his attention was drawn by Dr. J. W. Evans, senior Geologist to the Government of Mysore, to certain peculiarities of the so-called Champion reef in the Kolar gold-field, which show that it is not a reef or vein, but a true bed of metamorphic quartzite. The lie of the quartz is strictly conformable to that of the schists on either side, and in more than one place it has been bent sharply up and then down again into a synclinal and anticlinal fold, whose axis dip steeply to the northwards. Where the quartz is bent, the bedding of the hornblende schists follows it and can be seen curving over the vacant spaces where the quartz has been worked out. There can be little doubt that Dr. Evans' interpretation is the true one, and that the gold of Mysore, as of the Transvaal, occurs in a bed, and not in a true vein. This discovery is of interest as adding yet another to the many analogies between the geology of India and Africa, and is not without its bearing on the economic question of the life of the Kolar gold-field.

R. D. OLDHAM.

DONATIONS TO THE MUSEUM.

FROM 1ST AUGUST TO 31ST OCTOBER 1896.

SIX specimens of minerals, consisting of CYLINDRITE, from Poopoo, Bolivia; PERRYLITE, from Challacollo, Tarapaca, Chili; VESUVIANITE, from Magnet Cove, Arkansas, United States, America; SZAIBELYITE, from Rezbanya, Hungary; SPECULAR IRON, from Dognaczka, Hungary; OLIGOCLASE, from Hawk mine, Bakersville, Mitchell Co., North Carolina, United States, America; and five specimens of meteorites:—FOREST, Winnebago Co., Iowa, U. S. A., fell 2nd May 1890, weight 25 grms.; BATH, Aberdeen, Dacotah, U. S. A., fell 29th August 1892, weight 227 grms.; WICHITA Co., Brazos, Texas, U. S. A., found 1836, weight 287 grms.; CARLTON, Hamilton Co., Texas, U. S. A., found 1887, weight 86 grms.; PLYMOUTH, Marshall Co., Indiana, U. S. A., found 1893, weight 33 grms.

PRESENTED BY DR. ARISTIDES BREZINA,
DIRECTOR AM. K. K. NATURHISTORISCHEN HOFMUSEUM, VIENNA.

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